الجامعة التقنية الوسطى
المعهد التقني / بعقوبة
قسم تقنيـــات الكهربـــاء

الكترونيات القدرة 2

المرحلة الثانية

الفصل الدراسي الثاني

اعداد

أ.م. زهير سمين شكر

اسم المادة	لغة التدريس	السنة الدراسية	الفصل الدراسي	الفرع	الساعات الاسبوعية			الوحدات
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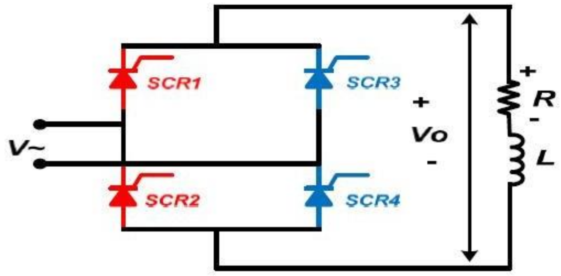
الكترونيات القدرة ٢	الانكليزية	الثانية	الاول	القوى الكهربائية	٢	٣	٥	٥

المفردات

Week	Theoretical syllabus
1^{st}	Regenrating fully controlled interters , examples , dc motor speed control.
2^{nd}	Three face inverters , output voltage wave from with , triggering pulses and equations.
3^{rd}	Thyristor protection from the high rate change in current and voltage , protection from the transient change in source voltage , fully protection circuit from all possible faults due to current and voltage .
4^{th}	Dc to ac inverters methods of forcing the thyristor to get off .
5^{th}	Parallel and senies inverter, single and three phase , control mdthods in charging frequency and voltage , output wave forms1 .
6^{th}	Inverter application , emergency power supply , single phase dc motor speed control.
7^{th}	Three phase motor control by using a constant ratio of variation frequency and voltage.
8^{th}	Choppers , dc to dc inverter frequency constant , line constant .
9^{th}	Types of choppers , dc motor speed control .
10^{th}	Ac to ac inverter , single phase voltage requlator , three phase voltage requlator .
11^{th}	General application on single and three induction motor speed control due to the change in stat or voltage , using the closed loop feedback circuit to control the dlippery rings of ac motor .
12^{th}	Cyclic inverter , ac to dc cyclic inverter , dc to dc cyclic inverter
13^{th}	Ac to ac cyclic inverter control black diagram .
14^{th}	Using amplitude modulation for speed control.
15^{th}	Using polar transistor for ac motor speed control .

Fully controlled full wave Rectifier: -



$$V_{d.c} = \frac{2V_m}{g}\cos\propto$$

If α >=90°

$$\therefore V_{d.c} = \frac{2V_m}{g}\cos 120 = \frac{-V_m}{g}$$

EX:- if L =50 mH , R= 10 Ω , α=30° , V= 325 sin 100π t Calculate :-

1- Vd.c

2- the angle of the load (Φ)

3- time to commutate the SCR

4- Discuss the waveform of (I load)

Solution :-

Vd.c = Vo = ∫α^(π+α) Vmsin(wt)d(wt) = (2 Vm)/π cosα

Vd.c = (2*325)/π cos30° = 179.2 v

tanΦ =WL/R

Φ = tan- 1 (100π*50*10-3)/10 = 57.5°

Wtq = β = π – α

tq = (π- α)/w = (π- (π/6))/100π = 8.3 msec

رامستمون يكل لحمراتيان فا (α)رلتأخيا يةر ون زاوكبا (Φ)للحما يةأن زاوبما

Converter Control of DC Machines

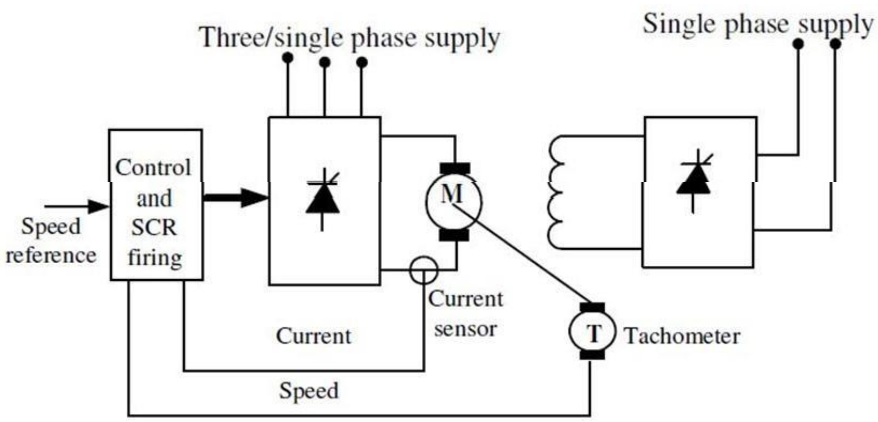
The speed of a dc motor can be controlled by controlling the dc voltage across its armature terminals. A phase controlled thyristor converter can provide this dc voltage source. For a low- power drive, a single-phase bridge converter can be used ,whereas for a high-power drive, a three- phase bridge circuit is preferred. The machine can be a permanent magnet or wound field type. The wound field type permits variation and reversal
of field and is normally preferred in large power machines.

DC Motor Drives:-

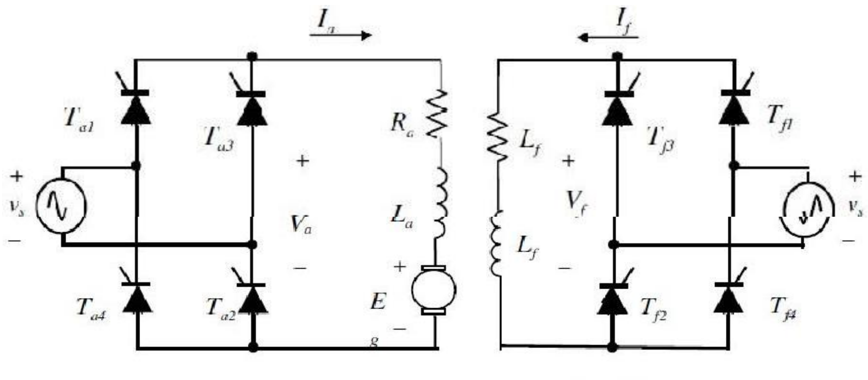
The DC drive is relatively simple and cheap (compared to induction motor drives). But DC motor itself is more expensive.

- Due to the numerous disadvantages of DC motor (esp. maintenance), it is getting less popular, particularly in high power applications.
- For low power applications the cost of DC motor plus drives is still economical.
- For servo application, DC drives is still popular because of good dynamic response and ease of control.
- Future Trend? Not so bright prospect for DC, esp. in high power drives.

Thyristor/SCR drives



Basic single-phase drive



For continuous current, armature voltage is:

$$V_a = \frac{2V_m}{\pi}\cos\alpha_a$$

Armature (DC) current is:

$$I_a = \frac{V_a - E_g}{R_a};\ E_g \text{ is the back emf}$$

Field voltage:

$$V_f = \frac{2V_m}{\pi}\cos\alpha_f$$

Example

Consider a 500V, 10kW , 20A rated- DC motor with armature resistance of 1 ohm. When supplied at 500V, the UNLOADED motor runs at 1040 rev/min, drawing a current of 0.8A (ideally current is zero at no-load).

- ***Estimate the full load speed at rated values***
- ***Estimate the no-load speed at 250V.***

Solution:-

$$V_a = I_aR_a + E_g = I_aR_a + K_v\omega I_f$$

$$K_vI_f = \frac{V_a - I_aR_a}{\omega} = \frac{500-0.8(1)}{1040} = 0.48$$

At full load and rated value,

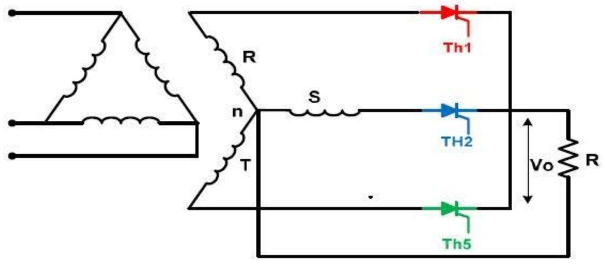
$$\omega_{fl} = \frac{V_a - I_aR_a}{K_vI_f} = \frac{500-20(1)}{0.48} = 1000 \text{ rev/min}$$

At no - load and voltage at 250V,

$$V_a = I_aR_a + K_v\omega I_f$$

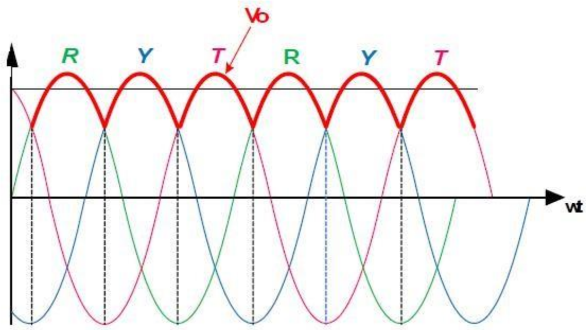
$$\omega = \frac{V_a - I_aR_a}{K_vI_f} = \frac{250-0.8(1)}{0.48} = 519 \text{ rev/min}$$

Three – phase convertors "three – phase controlled rectifiers " a- 3-Φ half wave rectifier with resistive load



a

$V_{RN} = Vm \sin wt$
$V_{YN} = Vm \sin(wt-120°)$
$V_{BN} = Vm \sin(wt +120°)$



b

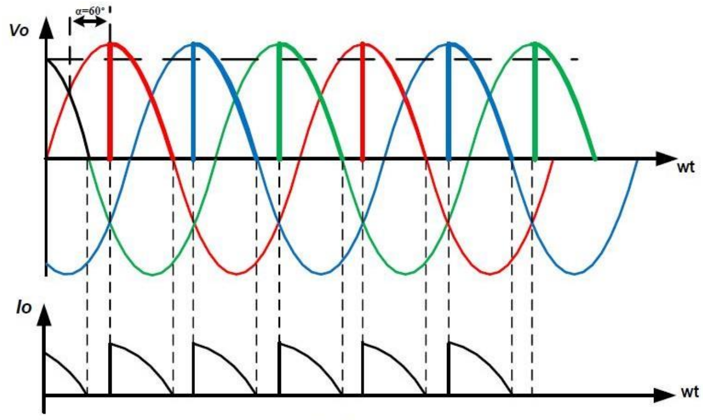
1- Continuous control:-

When α ≤ 30

$$V_O = 0.827 \ Vm \cos \alpha$$

2- Discontinuous control:-

When α > 30



The waveform of Vo and Io at α=60°

$$VO = \frac{3\,Vm}{2\pi}\left[1 + \cos\left(\frac{\pi}{6} + \alpha\right)\right]$$

EX:- ***A resistive load supplied from a 3-Φ half wave rectifier. if Vin=230 v (between Line and natural) calculate V_O at (α = π/6),(α =2π/3).***

Solution:-

Vdc = 0.827 Vm cosα

$Vm = \sqrt{2}\,\overline{V}_{RMS}$

= 1.4 *230 = 325 V

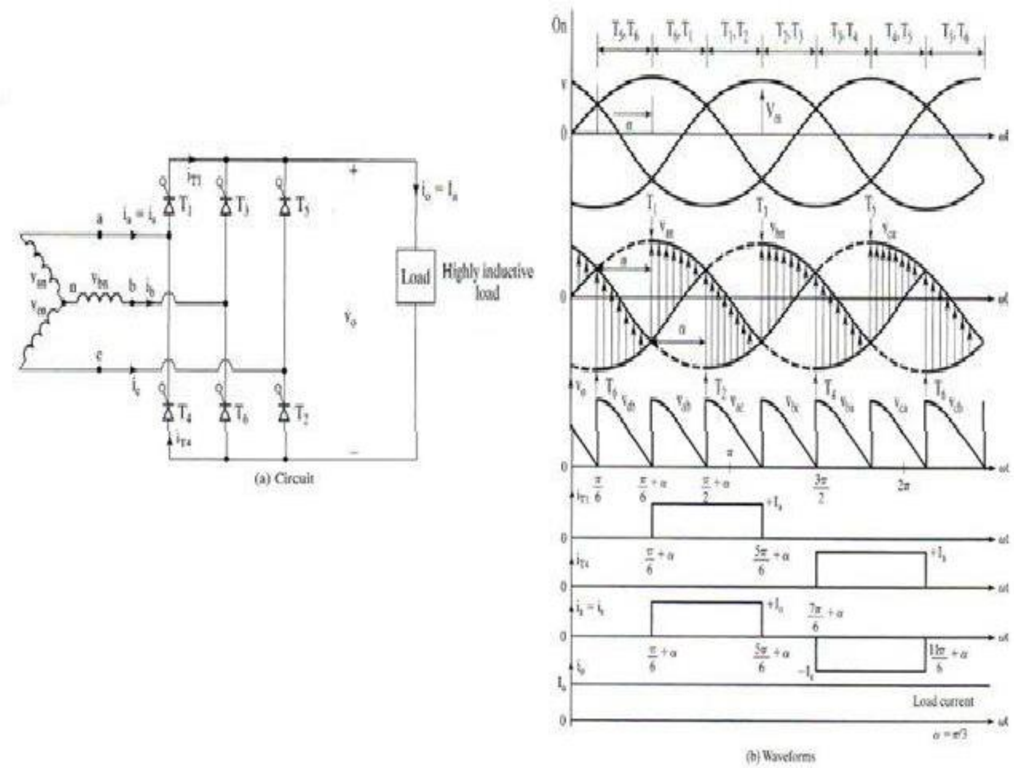
V_{dc} = 325 * 0.827 * cos 30°

V_{dc} = 281.65 v

When α = 2π/3 = 120° we have a discontinuity

V_O= *20.8 V*

Three phase full wave AC to DC converter:-

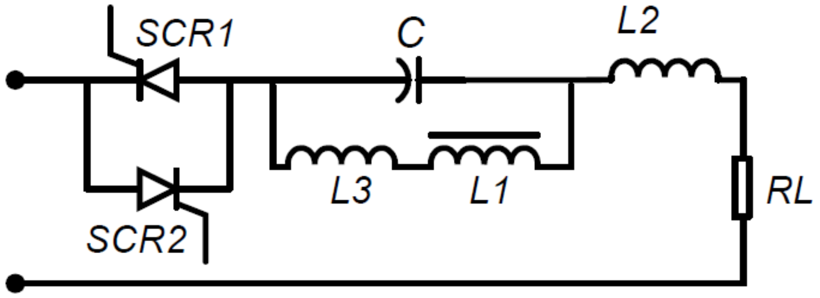


$$\bar{V}_O=\frac{3\sqrt{3}Vm}{\;}\qquad \cos \propto$$

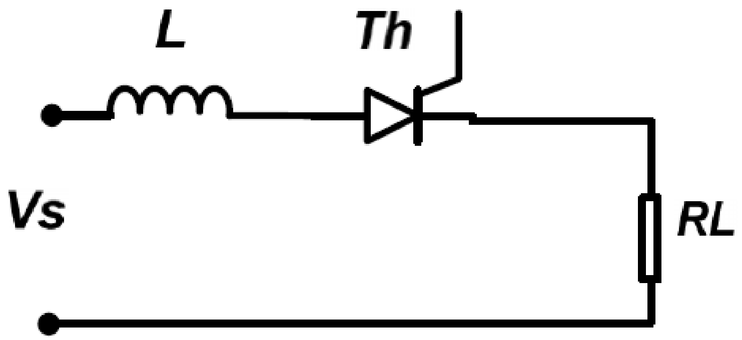
g

Thyristor protection circuits

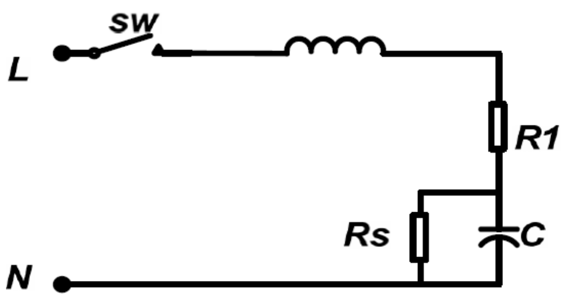
1- Thyristor protection from the increasing of the current



***2- Thyristor protection from the high rate of change in current* (di/dt).**



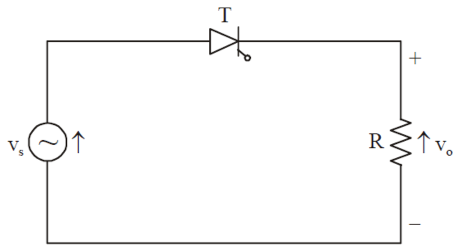
3- Protection from the transient change in source voltage



Methods of thyristor commutation:-

1- Natural commutation. (line commutation)

- **Natural Commutation of Thyristors takes place in:-**
- **– AC voltage controllers.**
- **– Phase controlled rectifiers.**
- **– Cyclo converters.**



Occurs in AC circuits

2- Forced commutation.

Applied to dc circuits

- **Commutation achieved by reverse biasing the SCR or by reducing the SCR current below holding current value.**
- **Commutating elements such as inductance and capacitance are used for commutation purpose.**

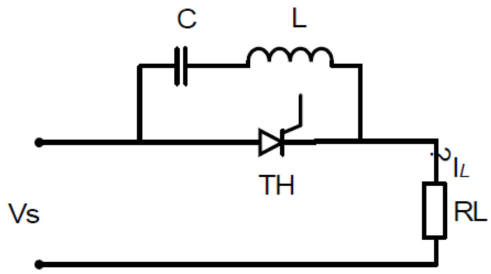
It is a technique used to forced the anode current to decrease to zero by using an external device connected to the thyristor for example applied proper inverse voltage or using another thyristor .

Forced Commutation is applied to

- **Choppers.**
- **Inverters.**

Kinds of commutation types:-

a-Self commutation



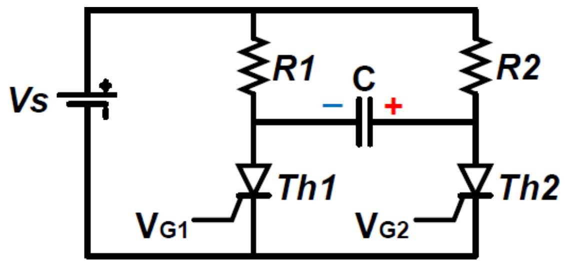
$I_m = 2L$

$C = \dfrac{0.4 t_{on}}{R_L}$

$L = \dfrac{C(R_L)^2}{4}$

b-commutation using external devices

1-*commutation using capacitor*: -



$Va1 = Vs - (1 - 2e^{-t/CR1})$

At Va1 =0

$t = 0.69CR1$ $\qquad$ $t = 2tg1$

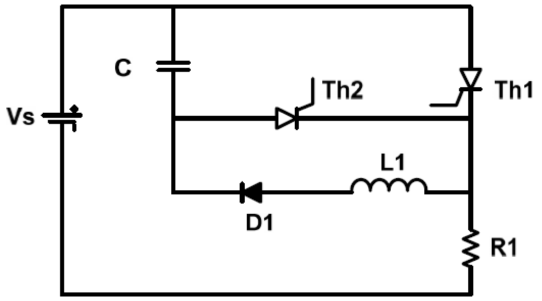
$Im(TH1) = \frac{2Vs}{R2} + \frac{Vs}{R1}$

$Im(TH2) = \frac{2Vs}{R1} + \frac{Vs}{R2}$

$I\,(rms) = \frac{2Vs}{R1}$

$P_{R1} = \frac{1}{2} * \frac{(Vs)^2}{R1}$ $\qquad$ $P_{R2} = \frac{1}{2} * \frac{(Vs)^2}{R2}$

2- *commutation by using a capacitor & thyresistor*



t = g mn = t ... = mn ,

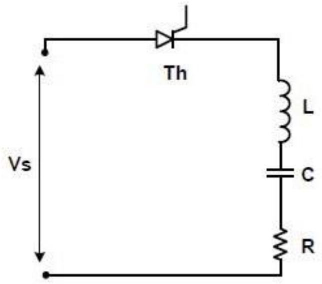
ردد

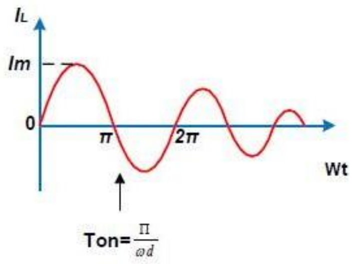
m n = 1/√LC

Im

Im = Vs J c/l

3- *commutation by using a series resonance circuit*:-





$m_d t = g$

t = g/md = ton $m_d = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

Im , = Vs / (m * L d)

$= m_d$ تردد الاشارة المتلاشية

H.W

FindCIF $m_d = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

Examples for commutation circuits

EX (1) In fig (1) find C and L . If I_L 3 A , Vs = 24 V ,ton = 5 msec ,R_L = 50 Ω Then Calculate Im .

Solve:-

$Im = 2L \qquad Im = 2 * 3 = 6\,A$

$$C = \frac{0.4ton}{RL}$$

$$C = \frac{0.4 * 5 * 10^{-3}}{50} = 40\,\mu F$$

$$L = \frac{40 * 10^{-6}(50)^2}{4} = 25\,mH$$

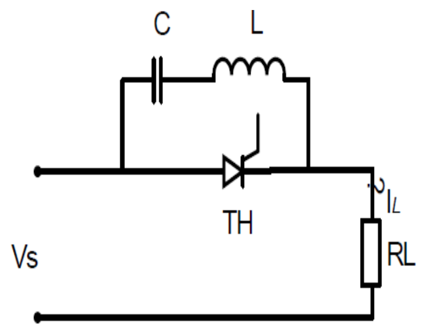


Fig (1)

****

EX (2) In fig (2) find C , Im(TH1) , Im(TH2) , I_m(rms) , P_{R1} , P_{R2} **. If I_L = 3 A , Vs = 50 V ,tg_1 = 20 μsec, tg_2 = 12 μsec ,R_1 = 100 Ω , R_2 = 82 Ω .**

Solve:-

$t = 0.69CR1 \qquad t = 2tg1$

$0.69CR1 = 2tg1 \qquad c = \frac{2tg1}{0.69R1}$

$$C = \frac{2 * 20 * 10^{-6}}{0.69 * 100} = 0.579\mu F$$

$0.68\mu F = C$ القيمة القياسية

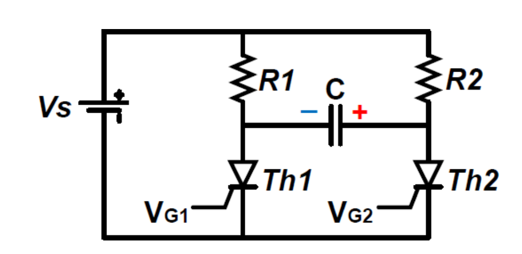


Fig (2)

$$Im(TH1) = \frac{2Vs}{R2} + \frac{Vs}{R1} = \frac{2 * 50}{820} + \frac{50}{100} = 0.62\ Amp$$

$$Im(TH2) = \frac{2Vs}{R1} + \frac{Vs}{R2} = \frac{2 * 50}{100} + \frac{50}{820} = 1\ Amp$$

$$I_T\,(rms) = \frac{2Vs}{R1} = \frac{2 * 50}{100} = 1\ Amp$$

$1 \qquad \frac{(Vs)^2}{} \qquad \frac{1}{} \qquad \frac{(50)^2}{}$

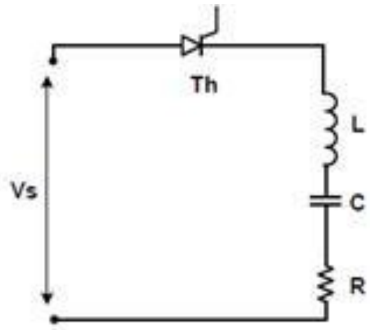
$P_{R1} = 2 * - \quad R1 \quad = 2 * \quad 100 = 12.5$ Watt ,

$1 \quad (Vs)^2 \quad 1 \quad (50)^2$

$P_{R2} = 2 * - \quad \frac{}{R2} = 2 * \quad \frac{}{820} = 1.5$ Watt

EX (3) In fig (3) find C . If RL = 150 Ω ,Vs = 24 V , ton 10msec IL (max) =3Amp

Solve .



Fig(3)

$m_d t = g$

$ton = \frac{g}{md}$, $md = \frac{g}{ton}$, $md = \frac{g}{10 * 10^{-3}} = 100g$

$Im = \frac{Vs}{m_d * L}$, $L = \frac{Vs}{m_d * Im} = \frac{24}{100g * 3} = 25 mH$

$m_d = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

$C = \frac{4L}{4L^2 m_d^2 + R^2}$

$C = \frac{4 * 25 * 10^{-3}}{4L(25 * 10^{-3})^2 (100 * g)^2 + (150)^2} = 4\ \mu F$

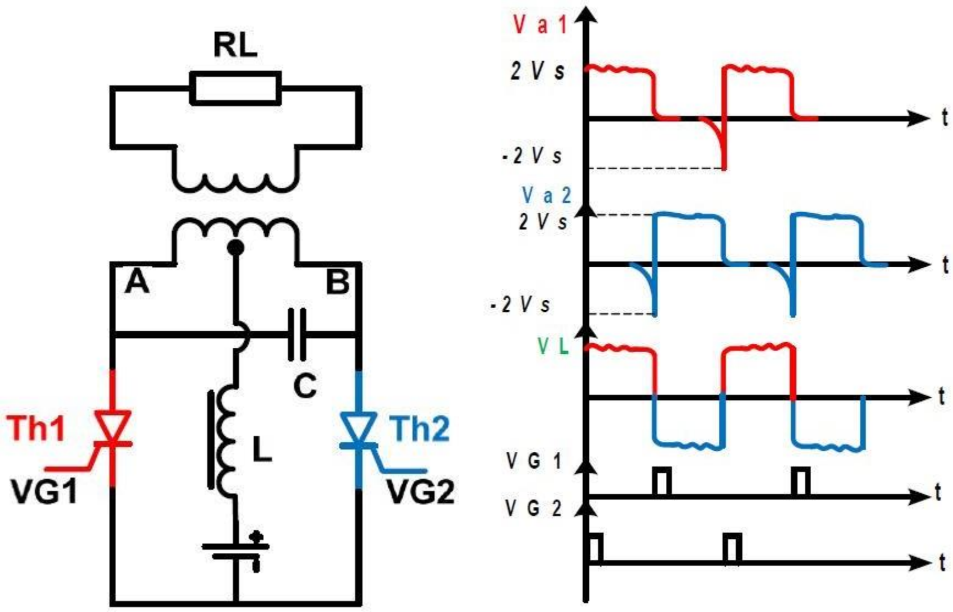
DC to AC Inverters

Inverter applications:-

1. **Speed control of motors .**
2. **Speed control of motors through the rotor .**
3. **DC to AC with AC to DC convertor in transmission line .**
4. **Flax heating .**

Kind of inverters

***1-parallel inverter*:-**



$F_{max} = \frac{N^2}{48*C*RL}$ $\quad$ $0.25 < \frac{ton}{toff} < 3.34$ $\quad$ $Ton = \frac{4*C*RL}{N^2}$ $\quad$ $Toff = \frac{N^2}{R}$

EX . Design a parallel inverter to generate square wave with frequency of (f=400HZ) to feed a resistive load its power (120W) with voltage of (240V) if you have a battery of 12volt

Solution:-

$$P = \frac{Vs^2}{R_L} \qquad RL = \frac{Vs^2}{P} = \frac{(240)^2}{120} = 480\Omega$$

$$N = \frac{V1}{V2} = \frac{240}{12} = 20$$

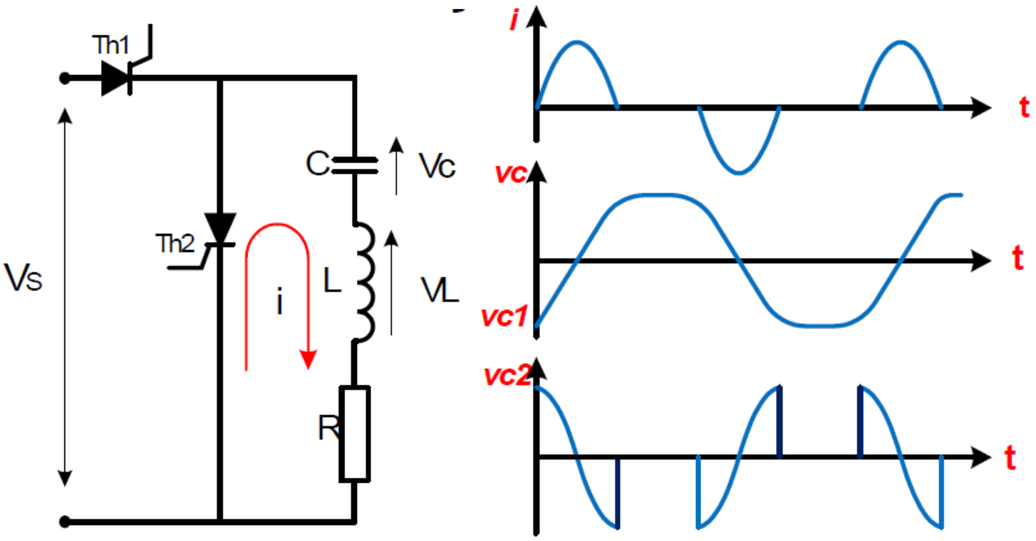
$$FMAX = \frac{N^2}{48CR_L}$$

$$C = \frac{n^2}{48\,R_L\ \ Fmax} = \frac{400}{48*480*400} = 43*10^{-6}\mu\,f$$

$$\frac{Ln^2}{R_L} = \frac{4\,C\,R_L}{3n^2}$$

$$L = \frac{4\,CR^2L}{3n^4} = \frac{4*47*10^{-6}*480^2}{3*20^4} = 90.24\,\mu\,H$$

2-series inverter:-



$$T = \frac{g}{m_d}$$

$\delta = \frac{R}{2L}$ δ (عامل التلاشي)

$$\delta * t = \frac{R}{2L} * \frac{g}{m_d} = 1$$

1- calculate (Vs):-

$$V_s = I\,R$$

$$I_m = \frac{(V_s+E_c)}{(m_d * L)} \quad \textbf{----------- (1)}$$

2- calculate (m_d):-

$$бt = 1 = \frac{R}{2L} * \frac{g}{m_d}$$

$$m_d\,L = \frac{gR}{2} \quad \textbf{---------- (2)}$$

Put (2) in (1)

$$I_m = \frac{2(V_s + E_c)}{g\,R}$$

$$E_C = 0.5V_s$$

$$V_s = \frac{g}{3}\, I_m\, R \qquad \text{(Vol t)}$$

3- calculate (L)

$$бt = \frac{R}{2L} * \frac{g}{m_d}$$

$$L = \frac{R}{2} * \frac{g}{m_d}$$

4- calculate (c)

$$m_d = \sqrt{\frac{1}{L\,C} - \frac{R^2}{4L^2}}$$

$$m_d^2 = \frac{1}{LC} - \frac{R^2}{4L^2}$$

$$C = \frac{4L}{\mu† \, 4L^2\, md^2 + R^2}$$

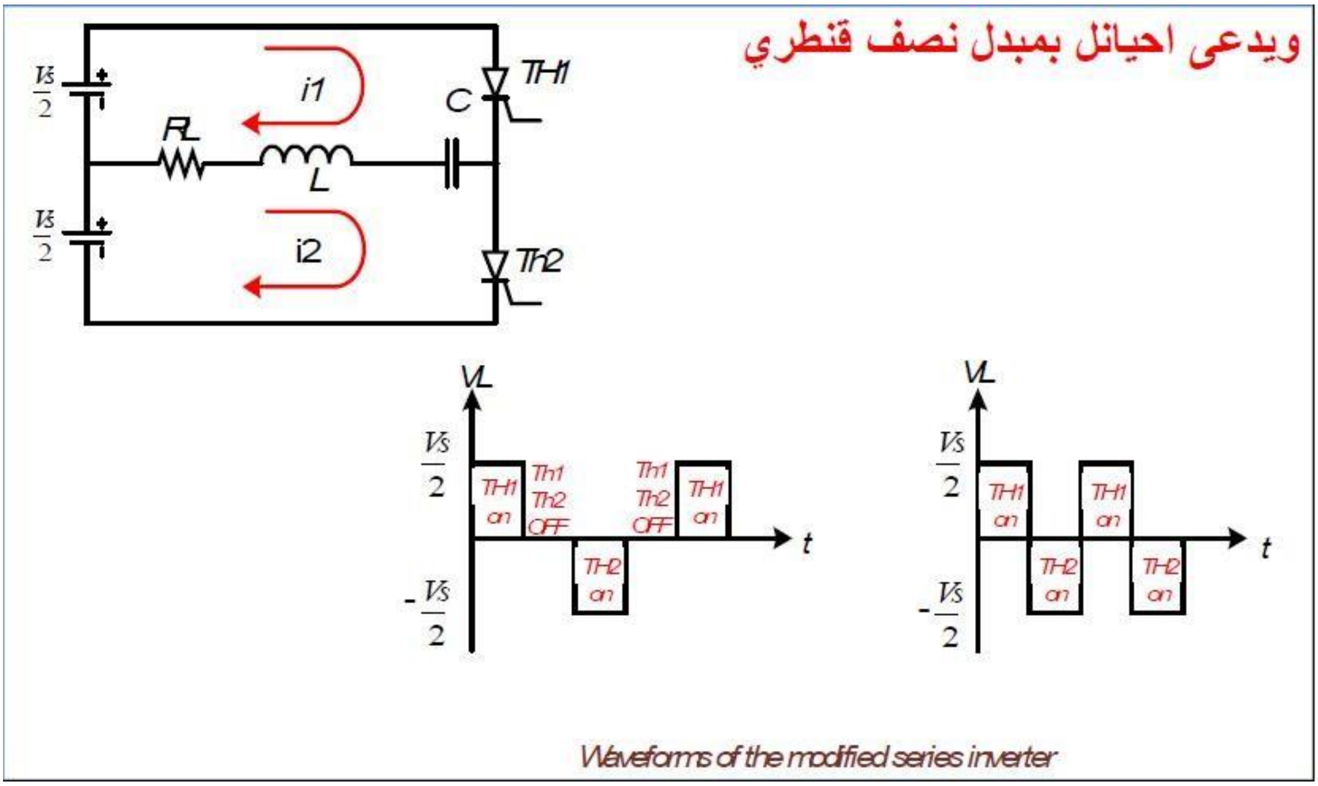
Disadvantage and limits of a series inverter

١تنتق -ل القدرةمـ ن المصدر المستمربشكـ لمتق ط .ع٢يكـ -ونمـ دى الترددلاشا رة الخرجصغيـ ار .
ويحسب اكبرتـ رددڤ على رضـ ت طابق جميع الظروف
والمواصفاتمـ ن المعادلة

$$\dagger max = \frac{1}{2(ton + tg)}$$

٣صعـ-وة بـقدح احد الثايرستوراتـقبـ ل إطفاء الثايرستور الآخر ، وتـحد بخلافهـدث دائرةقصـ ر على المصدر المستمر.
وللتغلب على هذه المساوئـتـحـ ور دائرة التوا لـيإشكـ لـيـ ل آخر.

Modified series inverter ((Half – bridge inverter))



Waveforms of the modified series inverter

EX :- ***Design an inverter circuit , so that the maximum value of the current (1 A) through resistance load of (150Ω) with frequency of (f = 400HZ) and the turn off time of the thyrister (25 µsec)***

Solution :-

$t = 1/f$ زمن الدورة الواحدة

$= 1/400 = 2.5$ msec

$T/2 = (2.5)/2 = 1.25 = 1250$ µsec

الا ان هذا الزمن يمثل زمن توصيل الثايريستور مضافا اليه زمن الاطفاء

$t/2 = t_{on} - t_q = 1250 - 25 = 1225$ µsec

$W_d = \pi/t = \pi/(1225 * 10^{-6})$

$= 2.56 * 10^3$ rad/sec

$V_S = \pi/3 \; Im \; R$

$= \pi/3 * 1 * 150 = 157$ VOLT

$$L = \frac{R}{2} * \frac{\pi}{Wd}$$

$$= \frac{150}{2} * \frac{\pi}{2.56 * 10^3} = 92 \text{ mH}$$

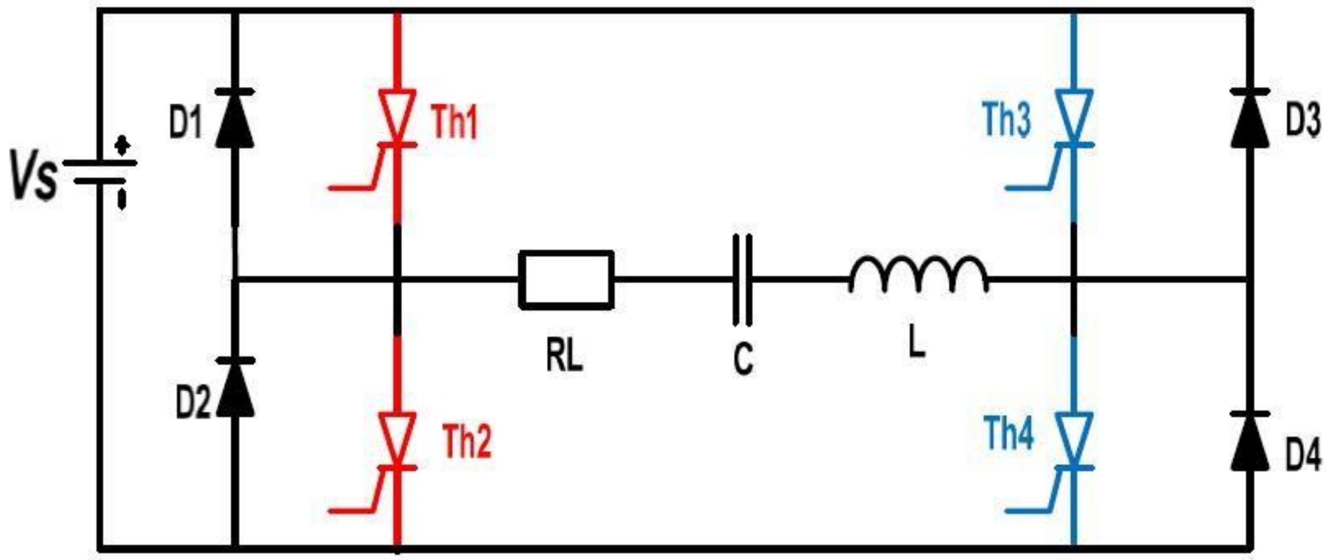
$$C = \frac{4L}{4L^2 \; Wd^2 + R^2}$$

$$= \frac{4 * 92 * 10^{\;3}}{4 * (92 * 10^{-3})^2 (2.56 * 10^3)^2 + (150)^2}$$

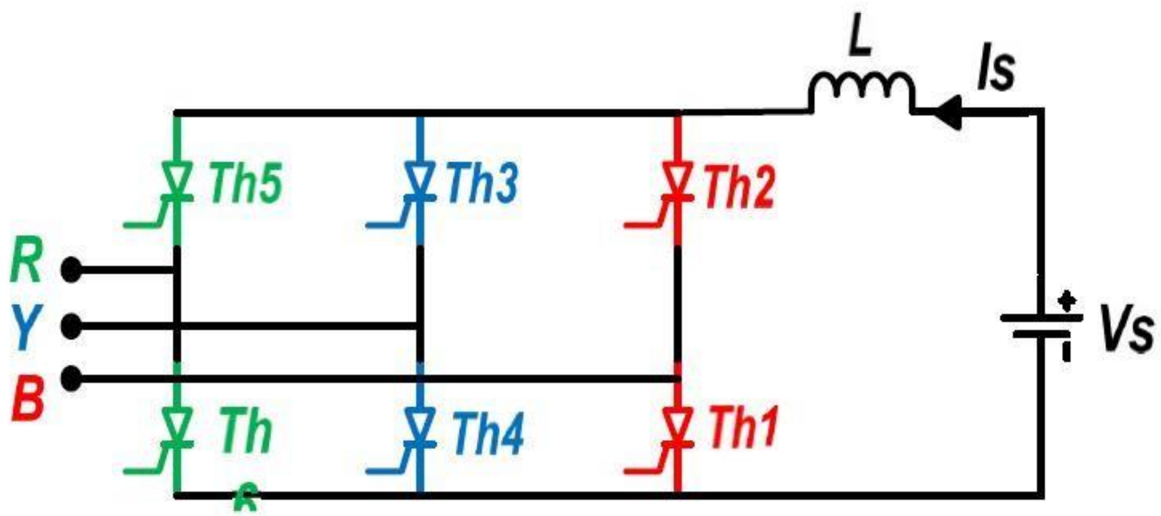
$= 15.7 \; \mu$

مبدل قنطرى احادى الطور

Single phase bridge inverter



Three phase inverter المبدلات ثلاثية الطور

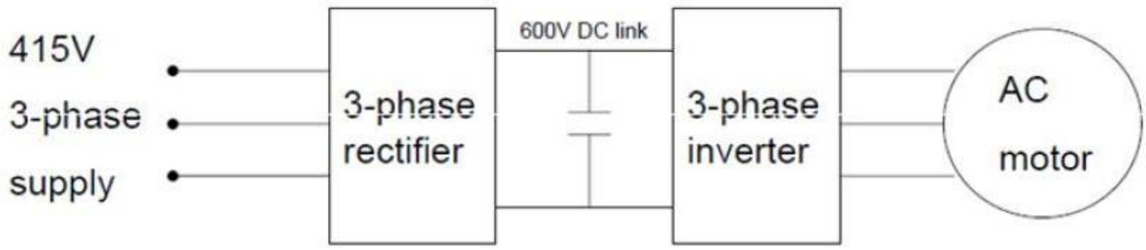


$V_O(wt) = V_{av} = (3\sqrt{3})/\pi \ \ V_m \cos\alpha$

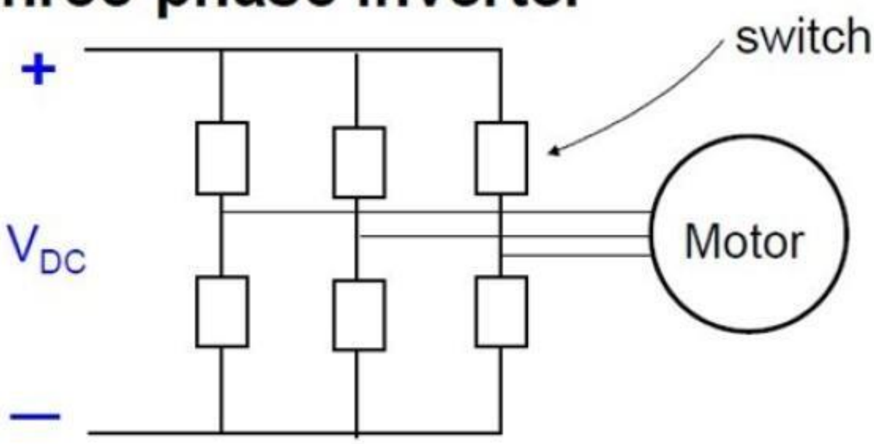
$I_L \ \ = \pm Vs/R$

Variable Speed AC Drive

- E.g. VVVF control of induction motor

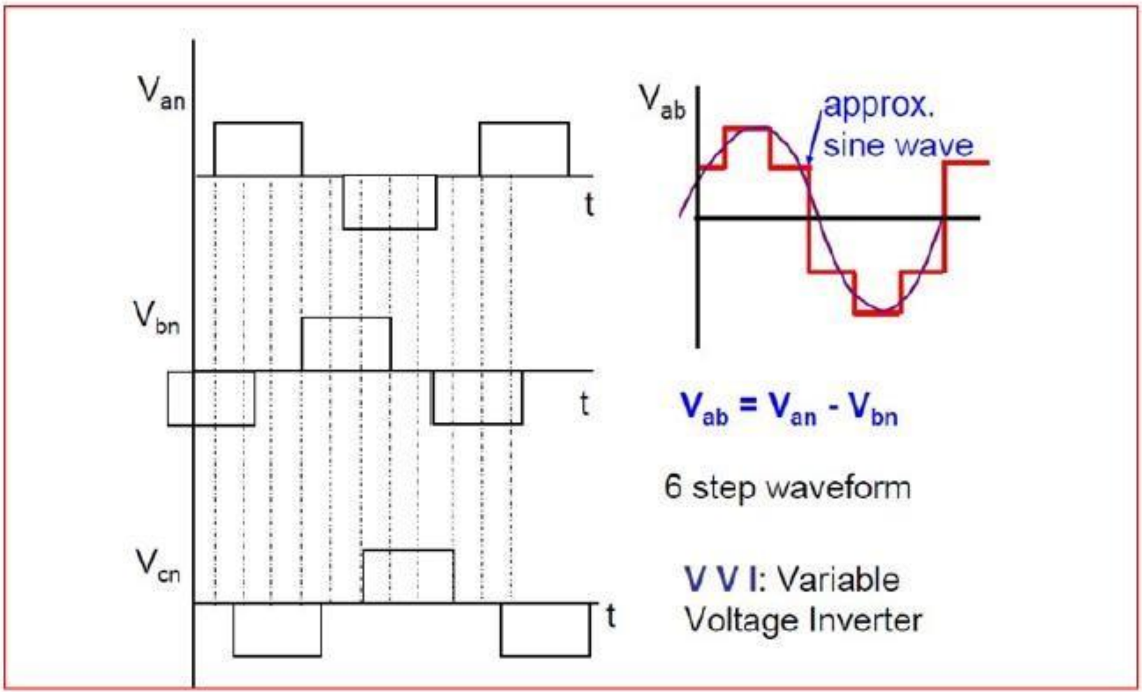


Three-phase inverter



harmonics in motor current cause heat & noise in windings. They create their own rotating fields which cause pulsating torques and vibration

Waveforms of voltages



Variable speed motor drives

* DC drives

▹ Power supply for DC motor

▹Usually controlled rectifier to convert constant AC to variable DC

*AC drives

▹Power supply for AC motor

▹Mostly for induction motors, but can be used with synchronous motors

▹Fixed AC →DC (fixed or variable) →Variable frequency and voltage AC

DC to AC Conversion

The converter that changes a DC to AC is called an inverter. Earlier inverters were built with SCRs. Since the circuitry required to turn the SCR off tends to be complex, other power semiconductor devices such as bipolar junction transistors, power MOSFETs, insulated gate bipolar transistors (IGBT) and MOS-controlled thyristors (MCTs) are used nowadays. Currently only the inverters with a high power rating, such as 500 kW or higher.

- Emergency lighting systems
- AC variable speed drives
- Uninterrupted power supplies
- Frequency converters.

EX .

Q: Write four applications of the inverter.

- Emergency lighting systems
- AC variable speed drives
- Uninterrupted power supplies
- Frequency converters.

DC TO DC CONVERTER

A step-down dc chopper with a resistive load is shown in Fig. (1. a) It is a series connection of a dc input voltage source *VS* , controllable switch S, and load resistance *R*. In most cases, switch S has a unidirectional voltage blocking capabilities and unidirectional current conduction capabilities. Power electronic switches are usually implemented with power MOSFETs,IGBTs, MCTs, power BJTs, or GTOs. If an antiparallel diode is used or embedded in a switch, a switch exhibits a bidirectional current conduction property. Figure (1.b) depicts waveforms in a step-down chopper. The switch is being operated with a duty ratio *D* defined as a ratio of the switch *on* time to the sum of the *on* the *off* times. For a constant frequency operation.

$$D = \frac{t_{on}}{t_{on} + t_{off}} = \frac{t_{on}}{T}$$

D نسبةالقطع

where *T*=1/*f* is the period of the switching frequency *f*. The average value of the output voltage is.

$$V_O = DV_S$$

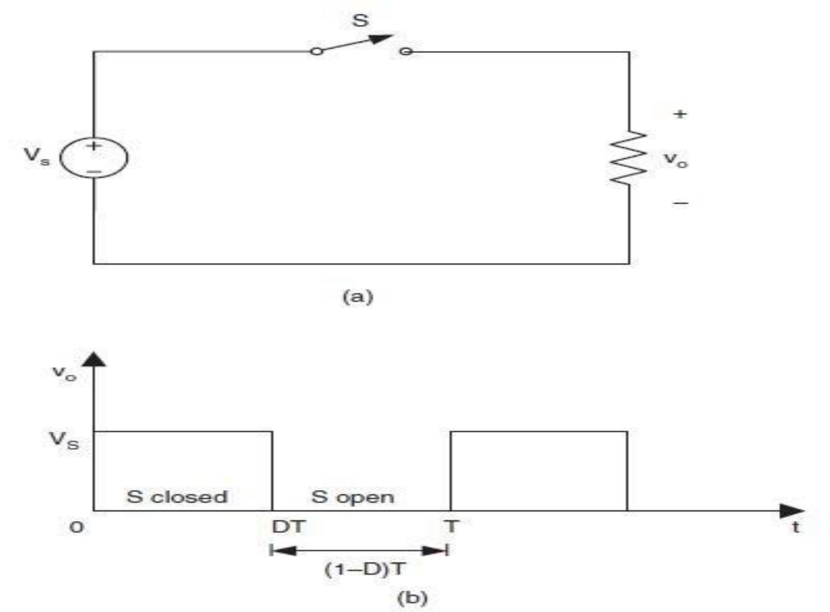


FIGURE 1 DC chopper with resistive load: (a) circuit diagram and (b) output voltage waveform.

and can be regulated by adjusting duty ratio *D*. The average output voltage is always smaller than the input voltage, hence,the name of the converter.

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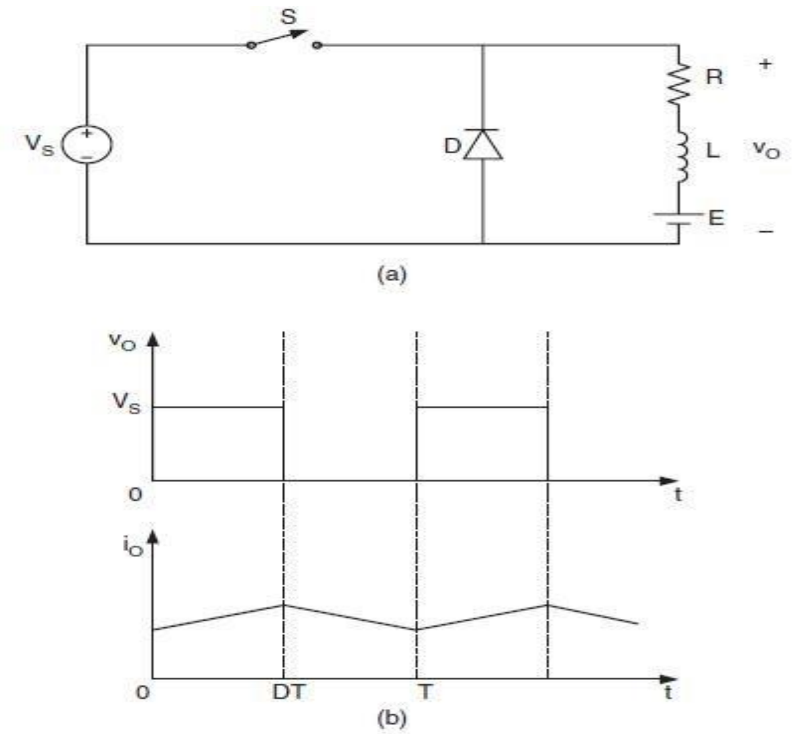


FIGURE 2 DC chopper with RLE load: (a) circuit diagram and (b) waveforms.

The dc step-down choppers are commonly used in dc drives. In such a case, the load is presented as a series combination of inductance *L*, resistance *R*, and back emf *E* as shown in Fig.(2a) To provide a path for a continuous inductor current
flow when the switch is in the *off* state, an antiparallel diode *D* must be connected across the load. Since the chopper of Fig. (2a) provides a positive voltage and a positive current to the load, it is called a first-quadrant chopper. The load voltage and current are graphed in Fig.(.2b) under assumptions that the load current never reaches zero and the load time constant

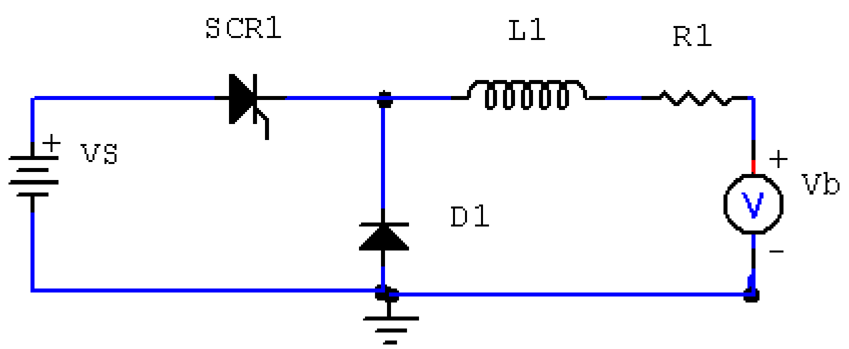
$$\tau = L/R$$

is much greater than the period *T*. Average values of the output voltage and current can be adjusted by changing the duty ratio *D*.

kinds of dc chopper converter

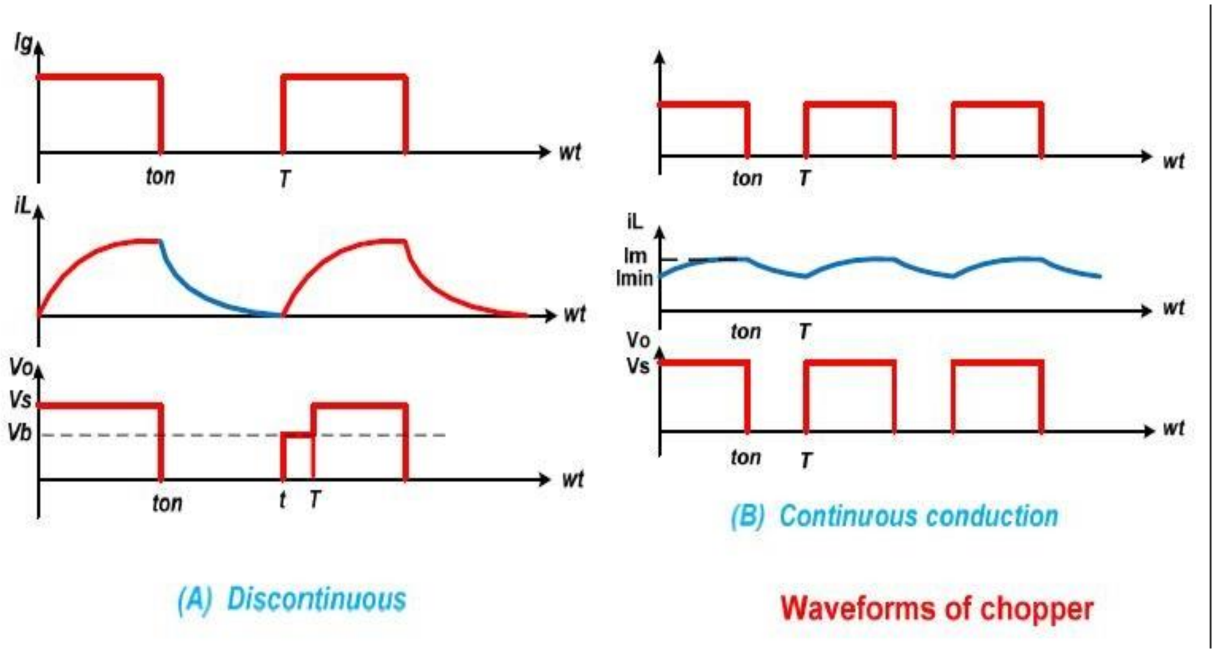
1- A step-down dc chopper:-

هناكء دة طرقلتقسيم المقطعاتحيث يمكن انتقسم محسب طرق الإخماد ا لمتبعةأوصنف العمل والشكل أدناهيمثل الدائرة المق لأساسيةطيعمعلمدى 90 (در) جة



حالة فيالأحمال المقاويك ميقون الشكل الموللتيا جير و الفولتية متماثلين ولاستخ حاجة لادامثنائي الإطلاق أما الأحمال افا لحثيةن الأشكال الموللتيا جيقر و الفوتك لتيقون مختلفة ومبيكمان بالإشكال الموجيةادناه.

ويكونتيا ر الحملمستمراحالة في الأحمال ا لحثيةالعالية حي فين يكونمتقطخلاعالفترة إطفاء الثايرستور



Waveforms of chopper

Discontinuous current condition:-

التشغيل لحالة التيار المتقطع

Vb = reverse emf

$$I_{L(m)} = \frac{[(Vs - Vb)]}{R}\left(1 - e^{\frac{-t}{\tau}}\right)$$

τ (time constant)

at t = ton IL =IL(max)

$$I_{L(m)} = IL(max) = \frac{[(Vs - Vb)]}{R}\left(1 - e^{\frac{-ton}{\tau}}\right)$$

continuous current condition:-

$$IL(max) = \frac{Vs}{R}\left(\frac{1 - e^{\frac{-ton}{\tau}}}{1 - e^{\frac{-T}{\tau}}}\right) - \frac{Vb}{R}\ (Amp)$$

$$IL(min) = \frac{Vs}{R}\left(\frac{e^{\frac{ton}{\tau}} - 1}{e^{\frac{T}{\tau}} - 1}\right) - \frac{Vb}{R}\ (Amp)$$

وت حالة في وصيل الثايرستور بشكل مستمر وبحيث يصبح (T=ton).

$$IL(max) = IL(max) = \frac{Vs - Vb}{R}\ (Amp)$$

EX 1 :- A D.C chopper operates to rang of (90^o) , fed from Supply of (60 V) ,the waveform of the load voltage formed of rectangular pulses each of width (2 ms) and
The periodic time of (5msec) ,Draw the waveform of the load voltage , then calculate the average output voltage .

Solve :-

$V_o = D V_s$

$D = \frac{t_{on}}{T}$, $V_o = \frac{t_{on}}{T} V_s = (\frac{2}{3}) * 60 = 24$ V

EX 2:- If the chopper in the ex(1) fed inductive load of (R= 5 Ω) and (L = 10 mH) .Calculate (Imin) and (Imax) of the load if the reverse (emf =0v) .

Solve :-

$t_{on} = 2$ msec T = 5 msec

$\tau = \frac{L}{R} = \frac{10}{5} =$ **2 msec.**

$$I_L(max) = \frac{V_s}{R}\left(\frac{1-e^{\frac{-t_{on}}{\tau}}}{1-e^{\frac{-T}{\tau}}}\right) - \frac{V_b}{R} \text{ (Amp)}$$

$$I_L(max) = \frac{60}{5}\left(\frac{1-e^{\frac{-2}{2}}}{1-e^{\frac{-5}{2}}}\right) - \frac{0}{5} \text{ (Amp)}$$

$$I_L(max) = \frac{60}{5}\left(\frac{1-e^{-1}}{1-e^{-2.5}}\right) - 0 = 8.25 \text{ (Amp)}$$

$$I_L(min) = \frac{V_s}{R}\left(\frac{e^{\frac{t_{on}}{\tau}}-1}{e^{\frac{T}{\tau}}-1}\right) - \frac{V_b}{R} \text{ (Amp)}$$

$$I_L(min) = \frac{60}{5}\left(\frac{e^{\frac{2}{2}}-1}{e^{\frac{5}{2}}-1}\right) - \frac{0}{5} \text{ (Amp)}$$

$$I_L(min) = \frac{60}{5}\left(\frac{e^{1}-1}{e^{2.5}-1}\right) - 0 = 1.84 \text{ (Amp)}$$

e − 1

EX 3 A DC Chopper circuit have :-

Vs = 100 V , T = 2.5 ms , ton = 1.25 ms , L = 0.2 H , R= 0.5 Ω

Vb = 50 V . Calculate :-

1-Output average voltage

2- Imax , Imin .

Solve ;-

$$Vo = \frac{t_{on}}{T} Vs = 100 * \frac{1.25}{2.5} = 50 \text{ v}$$

$$v = \frac{L}{R} = \frac{0.2}{0.5} = 0.4 \text{ msec}$$

$$\frac{t_{on}}{v} = \frac{1.25}{0.4} = 3.125 \ , \ \frac{T}{v} = \frac{2.5}{0.4} = 6.25$$

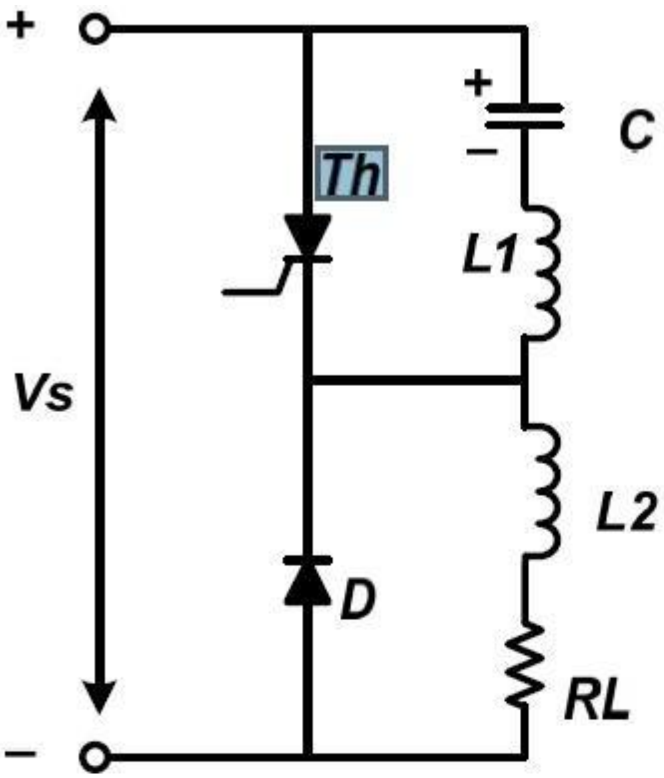
$$IL(max) = \frac{Vs}{R}\left(\frac{1 - e^{\frac{-ton}{v}}}{1 - e^{\frac{-T}{v}}}\right) - \frac{Vb}{R} \text{ (Amp)}$$

$$(IL \ max) = \frac{100}{0.5}\left(\frac{1 - e^{-3.125}}{1 - e^{-6.25}}\right) - \frac{50}{0.5} = 95.79 \ (Amp)$$

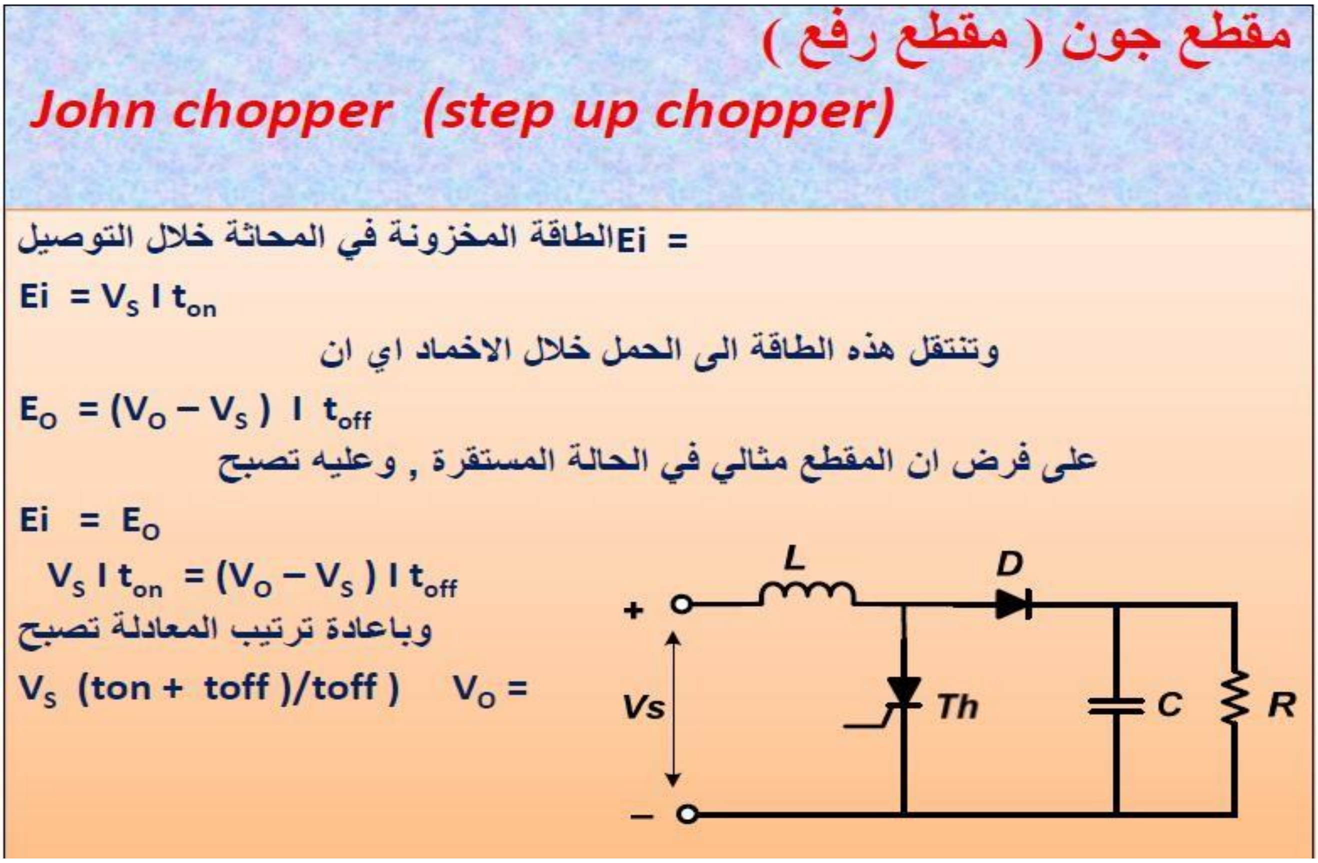
$$IL(min) = \frac{Vs}{R}\left(\frac{e^{\frac{ton}{v}} - 1}{e^{\frac{T}{v}} - 1}\right) - \frac{Vb}{R} \text{ (Amp)}$$

$$(IL \ min) = \frac{100}{0.5}\left(\frac{e^{3.125} - 1}{e^{6.25} - 1}\right) - \frac{50}{0.5} = 4.2 \ (Amp)$$

2-Morgan dc chopper:-



3 − JoMn cMopper (step up cMopper)



مغيرات التيار المتناوب الى متناوب A.C – A.C invertors

اكثر من تصنيف ويدخل في بنيتها الثايريستورات فقط , وذلك بسبب خاصية الفتح والغلق فيها , وتستغل هذه الخاصية للتحكم في القيمة الفعالة لجهد الحمل المتناوب الى صنفين رئيسين هما :-

اولا / منظمات الجهد للتيار المتناوب (AC voltage regulators)

وهي منظمات تقوم بتغيير قيمة القدرة الفعالة المجهزة الى دائرة حمل بعد استخدام الثايريستور بين المصدر والحمل

ثانيا / مغيرات الدورة (التردد) Cycle converters

تستخدم هذه المغيرات لتغيير المصدر المتناوب

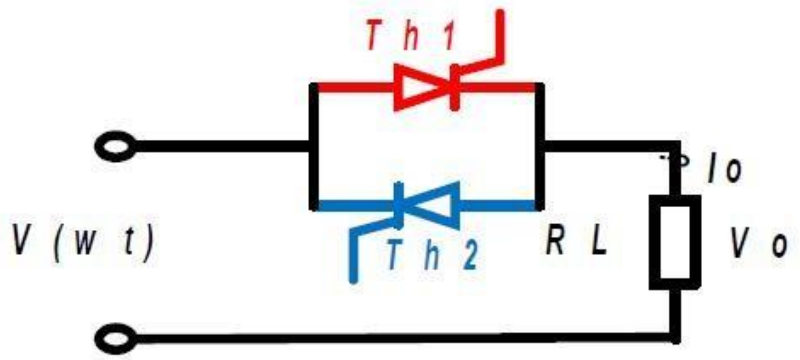
منظمات الجهد احاديه الطور 1- Φ voltage regulator

عند ربط زوج من الثايريستورات على التوازي المتعاكس فان المجموعة ستعمل كمفتاح الكتروني يناسب مصدرالتيار المتناوب

التحكم بطور واحد مع حمل مقاومي

2- Φ voltage regulator with resistive load

تعمل الثايريستورات بصورة متعاقبة ويكون جهد المصدر مسلط بشكل متناوب على الحمل



$V_s = V_m \sin(wt)$

بما ان الشكل الموجي للحمل يتكرر كل (π) من الزوايا نصف قطرية , فان القيمة الفعالة لجهد الحمل تكون :-

$$VO\,(rms) = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} Vm^2 \sin^2(wt)\, d(wt)}$$

$$VO\,(rms) = \frac{Vm}{\sqrt{2}}\sqrt{\frac{\pi - \alpha + \frac{1}{2}\sin 2\alpha}{\pi}}$$

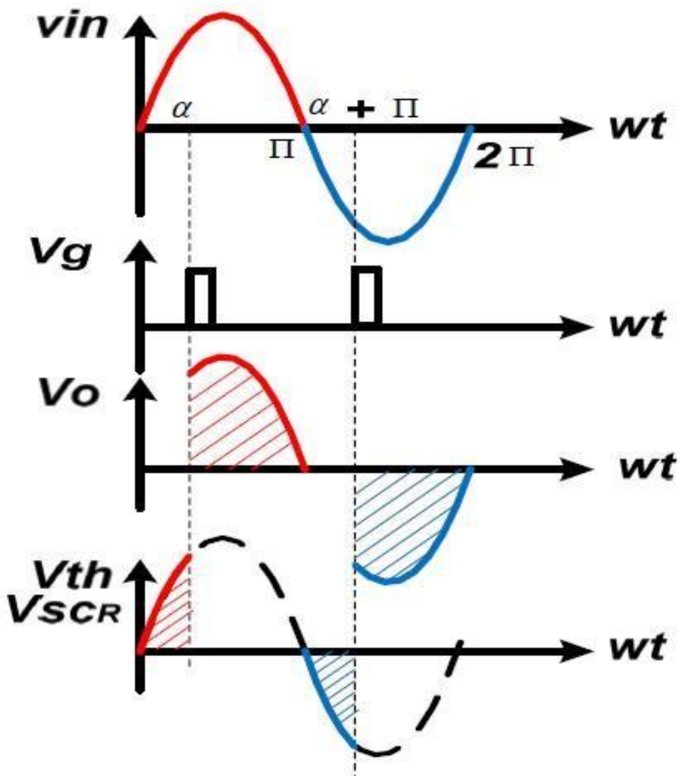
تحسب القيمة الفعالة لتيار الحمل كالاتي

$$IO\,(rms) = \frac{Vm}{\sqrt{2}\,R_L}\sqrt{\frac{\pi - \alpha + \frac{1}{2}\sin 2\alpha}{\pi}}$$

تحسب قدرة الحمل وعامل القدرة من العلاقات

$$PO\,(rms) = \frac{Vo^2\,(rms)}{R_L}$$

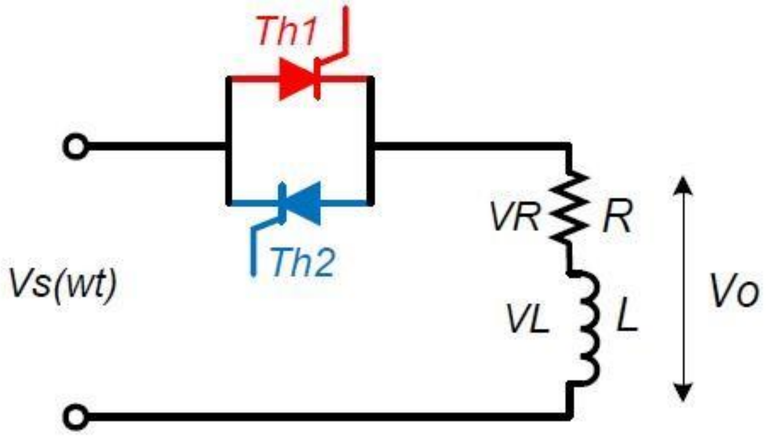
$$P.F = \sqrt{\frac{\pi - \alpha + \frac{1}{2}\sin 2\alpha}{\pi}}$$



Waveforms of asingle phase regulator with resistive load

التحكم احادى الطور مع حمل حثي

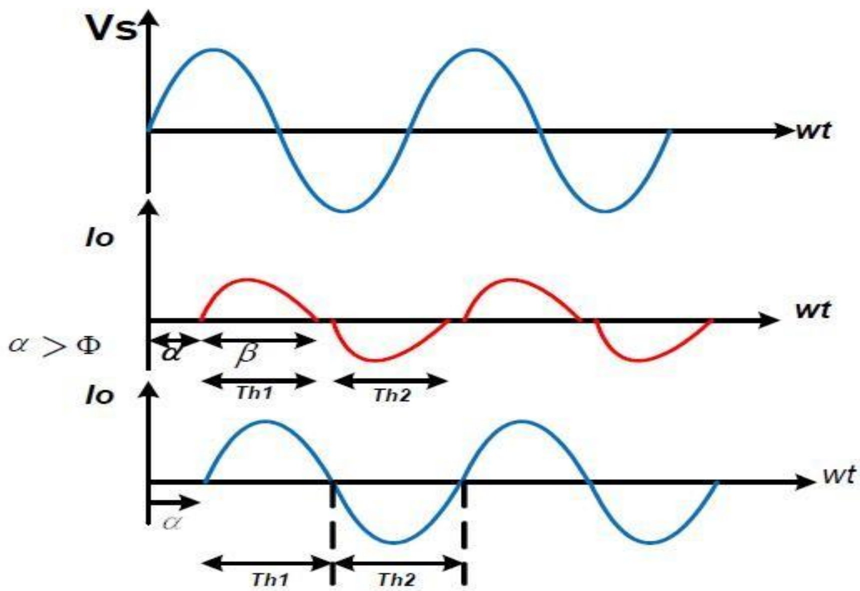
Single phase controller with inductive load



$V_S = V_{th} + V_R + V_L = V_{th} + V_O$

$\Phi = \tan^{-1} WL/R$

ثابت الزمن Time constant = L/R



Waveforms of the voltageregulater with inductive load

EX:- ***A pair of thyristors are connected in parallel (reversely) to control the power of a resistive load has resistance of (R=12 Ω) if the $V_{r.m.s}$ of the supply is $V_{r.m.s}$ = 230 , with f= 50 HZ , firing angle α = 60° calculate***

1- $V_{r.m.s}$, $I_{r.m.s}$, of the load

2-The dissipation power in the load, the power factor of the A.C supply

Solution:-

$$VO\,(rms) = \frac{Vm}{\sqrt{2}}\sqrt{\frac{\pi \quad \alpha \;\; \frac{1}{2} \quad sin2\alpha}{\pi}} = 230\sqrt{\frac{\pi - \frac{\pi}{3} + \frac{1}{2} \quad sin(\frac{2\pi}{3})}{3.14}}$$

= 167.26 volt

$$IO\,(rms) - \frac{V_{0\,(rms)}}{R_L} = \frac{167.26}{12} = 13.94\,A$$

$$PO\,(rms) - \frac{Vo^2\,(rms)}{R_L} = \frac{(167.26)^2}{12} - 2.33\,K.W$$

$$P.F = \sqrt{\frac{\pi - \alpha + \frac{1}{2} \quad sin2\alpha}{\pi}} \qquad \sqrt{\frac{\pi - \frac{\pi}{3} + \frac{1}{2} \quad sin(2 * 60)}{\pi}} = 0.72$$

EX:- ***A pair of thyristors are connected in parallel (reversely) to control the power of an inductive load if the time constant L/R = (10 msec) , find the width of the firing pulse to generate a wave shape similar of that of the load current .(f = 50 HZ)***

Solution :-

Φ = tan^{-1} WL/R

= tan^{-1} (2 π f (L/R)) = tan^{-1} (2 π * 50 *10*)

= 72°

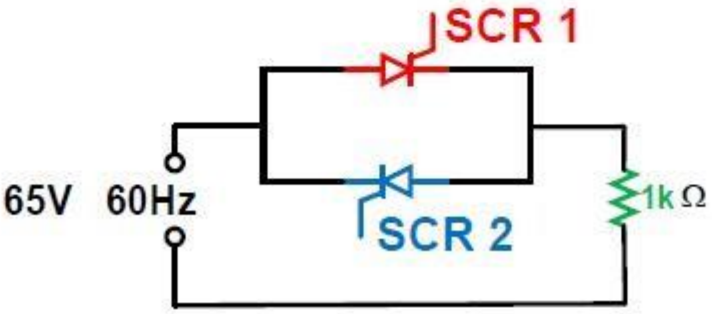
اقل عرض لنبضة القدح يمثل الفرق بين زاويتي ممانعة الحمل ولبقدح لذن عرض النبضة سيكون :-

Φ – α = 72° - 60°

= 12°

Q1: For the circuit shown calculate :

I_{rms} and P_{orms} , PF of that of the load current , when (α = 90º)



$$V_O\,(rms) = \frac{Vm}{\sqrt{2}}\sqrt{\frac{\pi - \alpha + \frac{1}{2}\sin 2\alpha}{\pi}}$$

$$= \frac{65 \times \sqrt{2}}{\sqrt{2}}\sqrt{\frac{\pi - \frac{2\pi}{3} + \frac{1}{2}\sin 2 \times 90}{3.14}}$$

$$Iorms = \frac{Vorms}{RL} = \frac{61.98}{1000}$$

$$= 6.198 * 10^{-3} \quad Amp$$

$$Porms = \frac{Vorms^2}{RL} = \frac{61.98^2}{1000}$$

$$P_{Orms} = 0.384 \text{ wat}$$

$$PF = \frac{Porms}{Pin} = \frac{61.98}{87.98} = 0.70$$

..

Cycloconverters

***Cyclo-Converters are direct ac-to-ac frequency changers.*The term direct conversion means that the energy does not appear in any form other than the ac input or ac output. The output frequency is lower than the input frequency and is generally an integral multiple of the input frequency.**

***A cyclo-converter permits energy to be fed back into the utility network without any additional measures. Also, the phase sequence of the output voltage can be easily reversed by the control system.**

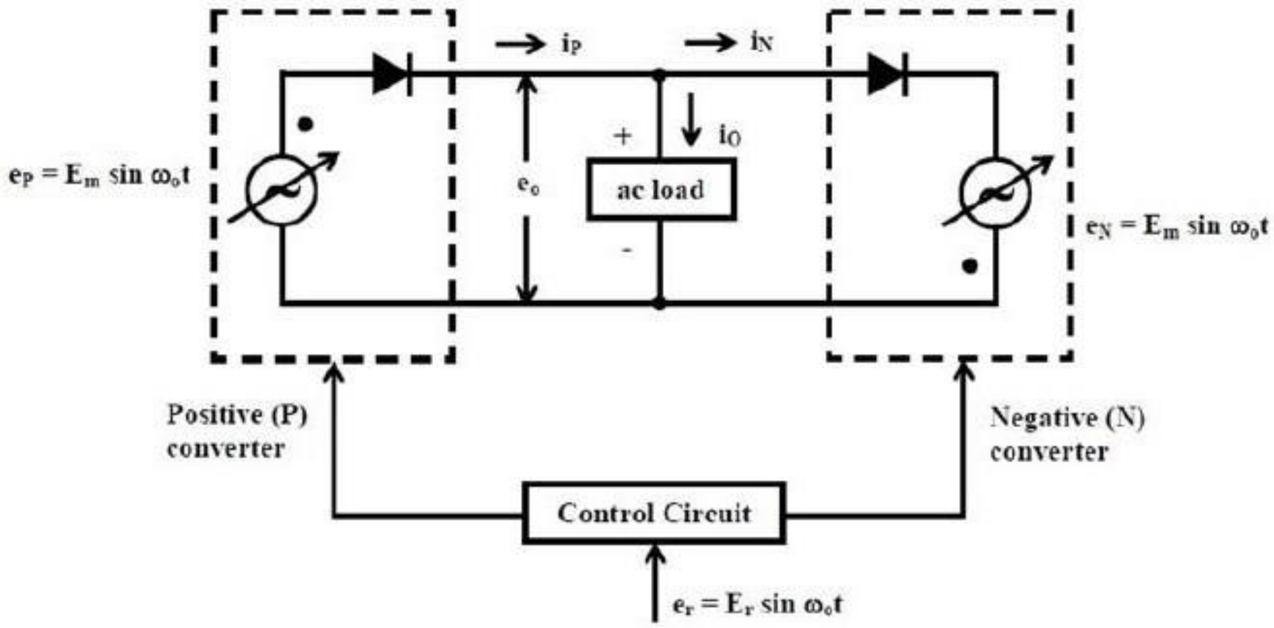
***Cycloconverters have found applications in aircraft systems and industrial drives. These cycloconverters are suitable for synchronous and induction motor control.**

Cycle-converters

- *** AC power at one frequency is converted directly to an AC power at another frequency without any intermediate DC stage.**
- *** The output of cycloconverter provides ac power at a lower frequency than input.**
- *** Bidirectional power-flow is possible.**
- *** Able to operate with loads of any power factor.**
- *** Generally, output frequency is lower than source frequency.**
- *** input power factor is worse if the fabricated output voltage is decreased.**

Basic Principle of Operation

The basic principle of operation of a cyclo-converter is explained with reference to an equivalent circuit shown in Fig. Each two-quadrant converter (phase-controlled) is represented as an alternating voltage source ,which corresponds to the fundamental voltage component obtained at its output terminals. The diodes connected in series with each voltage source, show the unidirectional conduction of each converter, whose output voltage can be either positive or negative, being a two-quadrant one, but the direction of current is in the direction as shown in the circuit, as only thyristors – unidireconal switching devices, are used in the two converters. Normally, the ripple content in the output voltage is neglected.



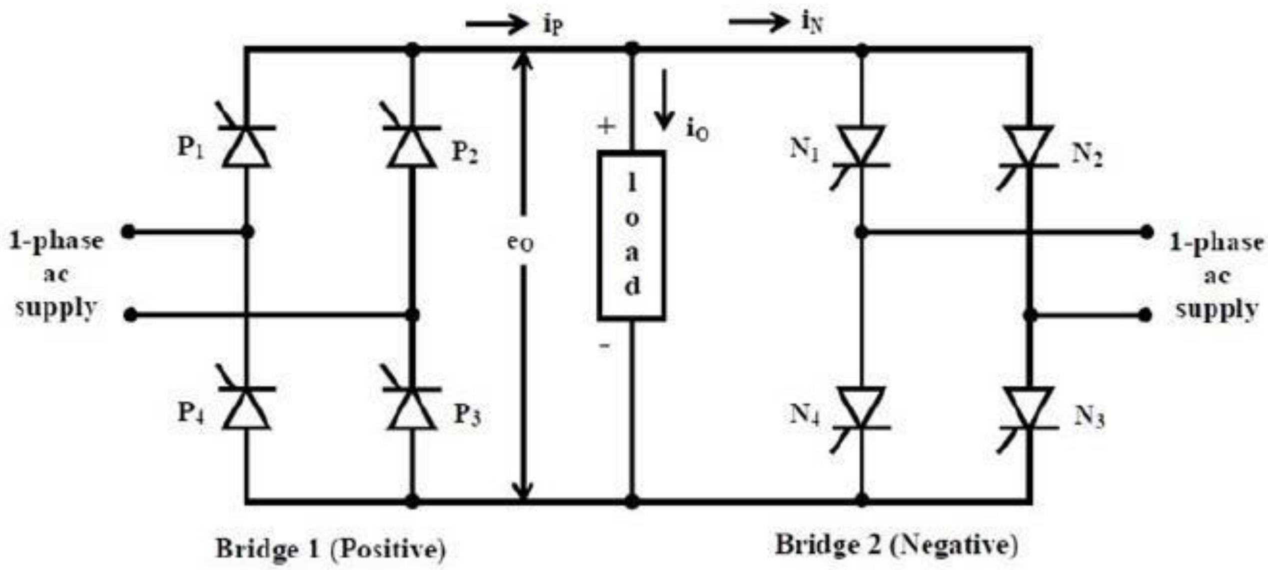
Equivalent circuit of cyclovonverter

Working Principle

* Fundamental wave is generated by the two, 2- quadrant phase converters.
* Diode for unidirectional conduction.
* Ripple content is neglected.

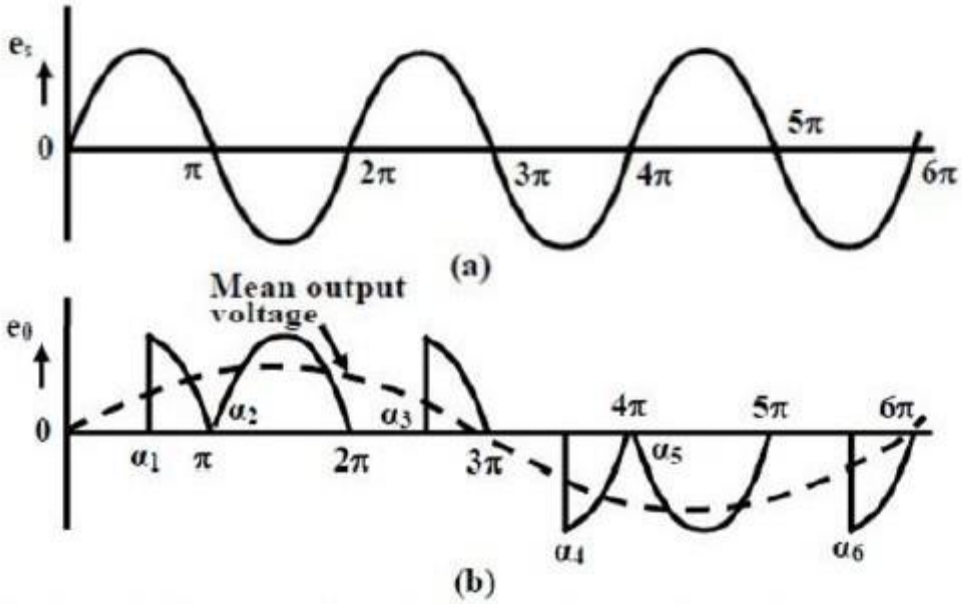
*Positive current is carried by positive converter and negative by negative.

Single-phase to Single-phase Cycle-converter



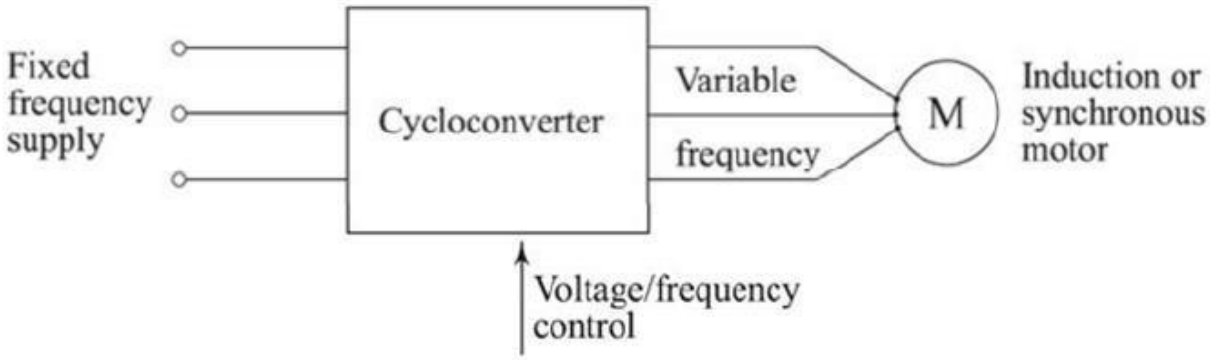
Single-phase to single-phase cycloconverter (using thyristor bridges)

Resistive (R) Load



Input (a) and output (b) voltage waveforms of a cyclo-converter with an output frequency of $16\frac{2}{3}$ Hz for resistive (R) load

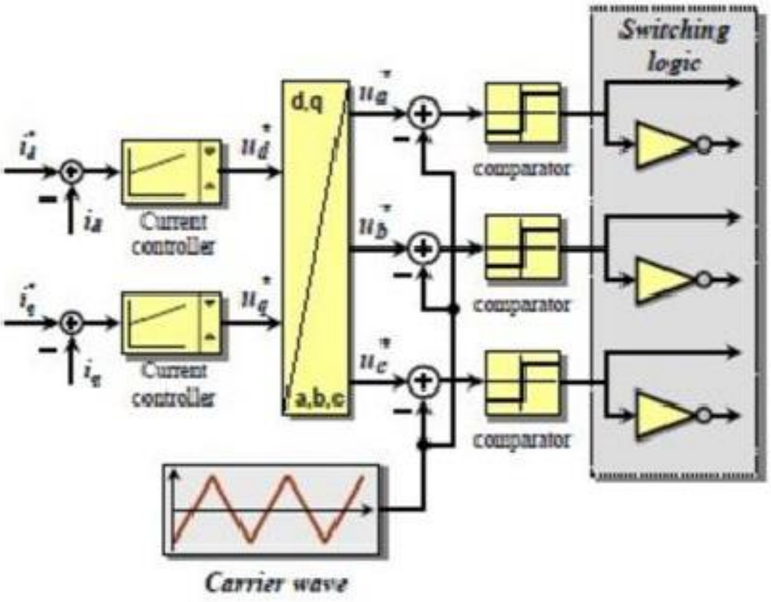
Cycloconverter Control of AC drives



Cycloconverter control

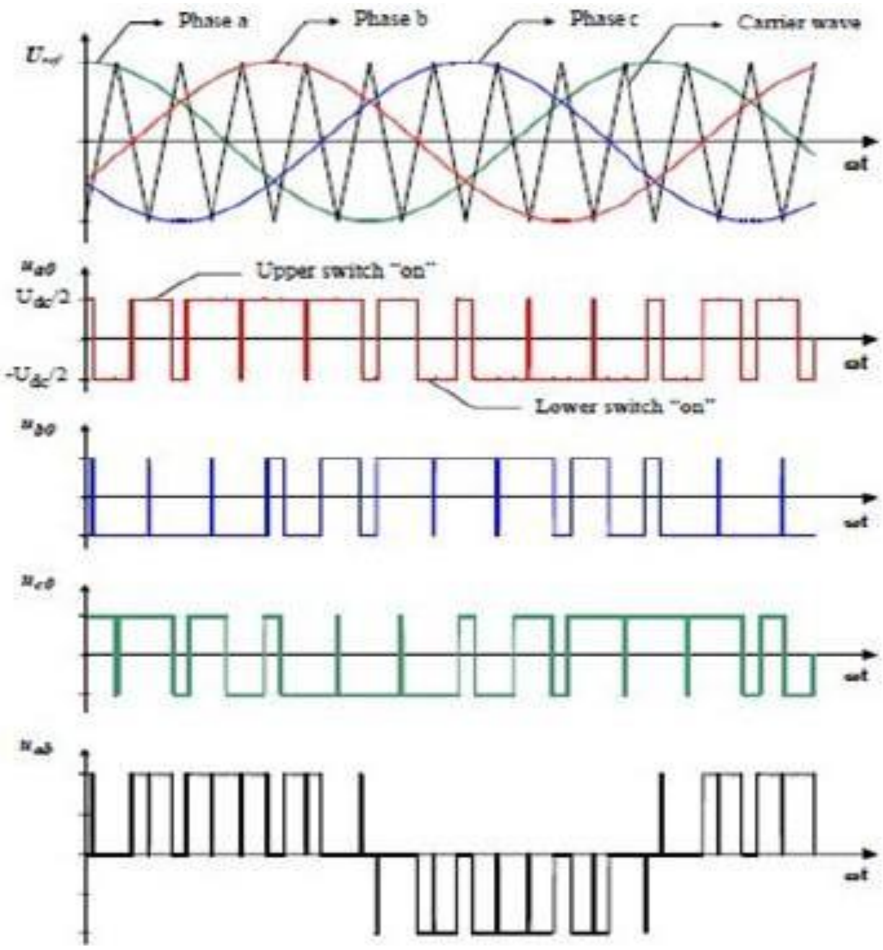
Sinusoidal Pulse Width Modulation

Three-phase reference voltages of variable amplitude and frequency are compared in three separate comparators with a common triangular carrier wave of fixed amplitude and frequency (figure).



Sinusoidal PWM, current control and switching logic.

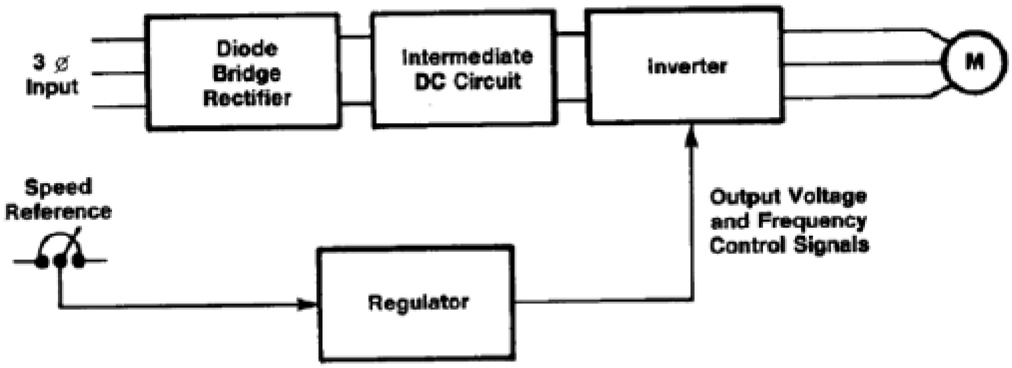
saw-tooth- or triangular-shaped carrier wave



Pulse Width Modulated (PWM)

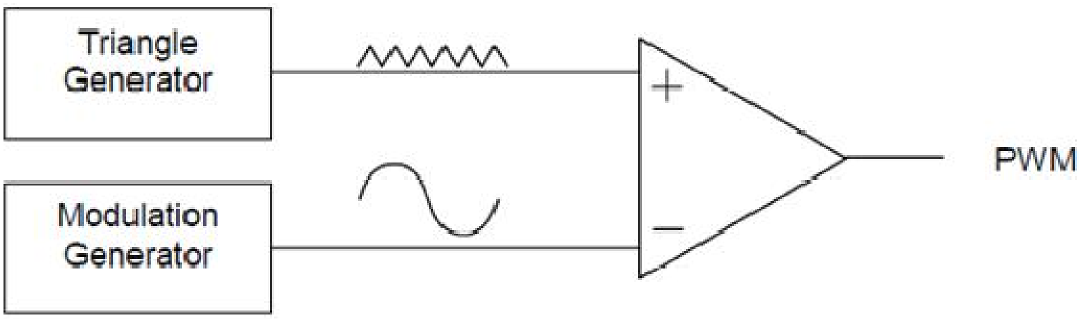
Figure (below) shows a block diagram of the power conversion Unit in a PWM drive. In this type of drive, a diode bridge Rectifier provides the intermediate DC circuit voltage. In the intermediate DC circuit, the DC voltage is filtered in a LC low pass filter. Output frequency and voltage is controlled electronically by controlling the width of the pulses of voltage to the motor. Essentially, these techniques require switching the inverter power devices (transistors or IGBTs) on and off many times in order to generate the proper RMS voltage level.

Power Conversion Unit (PWM)

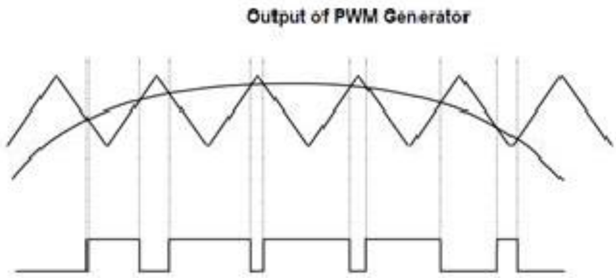


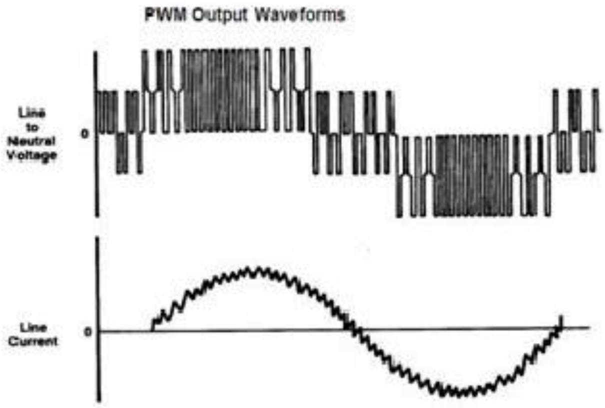
This switching scheme requires a more complex regulator than the VVI. With the use of a microprocessor, these complex regulator functions are effectively handled. Combining a triangle wave and a sine wave produces the output voltage waveform.

PWM Generator



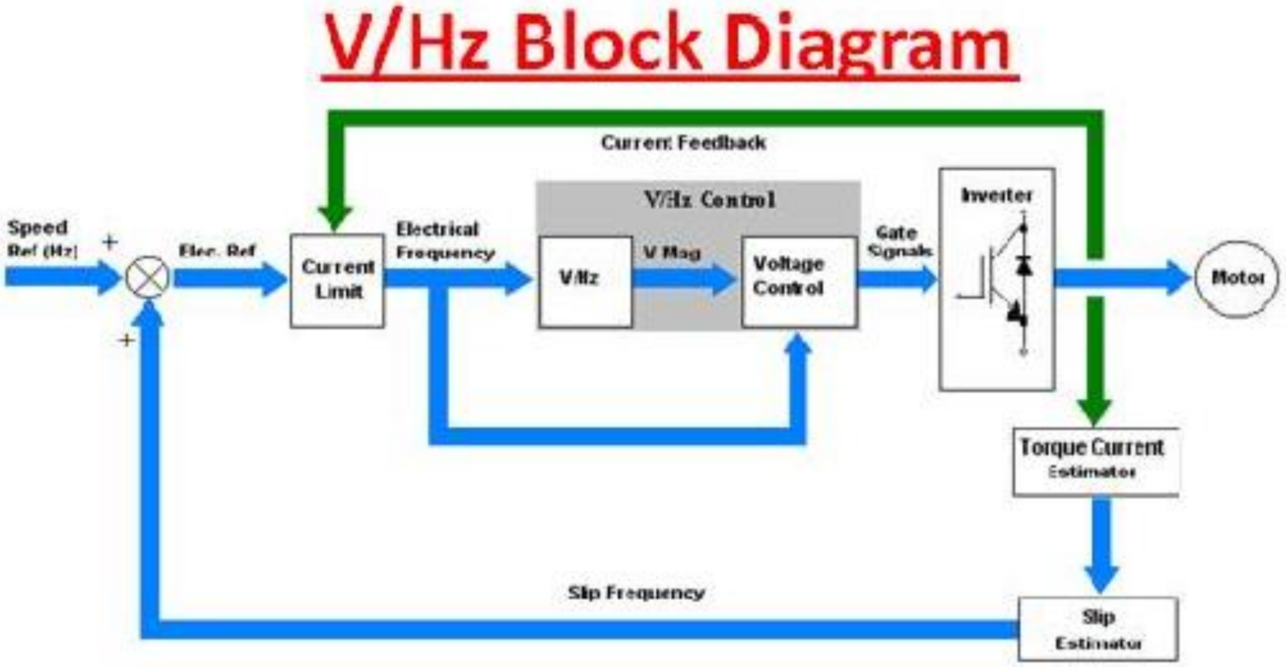
The triangular signal is the carrier or switching frequency of the inverter. The modulation generator produces a sine wave signal that determines the width of the pulses, and therefore the RMS voltage output of the inverter.





Volts/Hertz

Volt/Hertz control in its simplest form **takes speed reference command from an external source and varies the voltage and frequency applied to the motor. By maintaining a constant V/Hz ratio, the drive can control The speed of the connected motor.**



Typically, a current limit block monitors motor current And alters the frequency command when the motor current exceeds a predetermined value.

Three phase voltage regulator

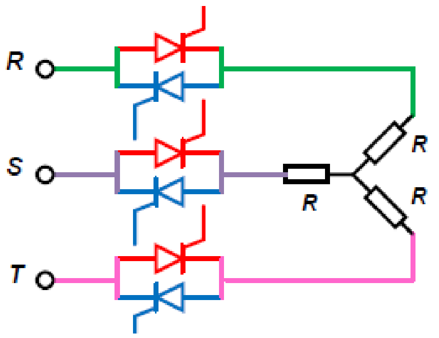
$VR = Vm\sin(mt)$

$VR = Vm\sin(mt - 120^o)$ VR

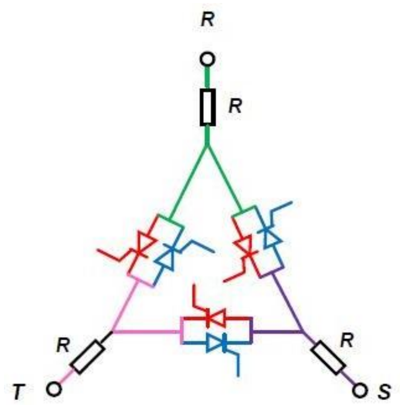
$= Vm\sin(mt + 120^o)$

There are three model for three phase voltage regulator

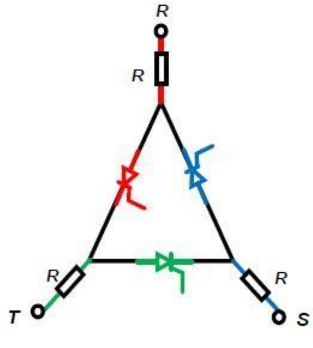
1-



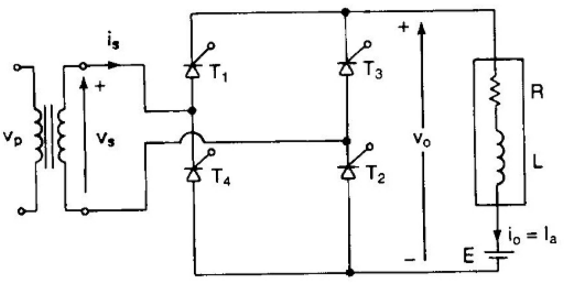
2-

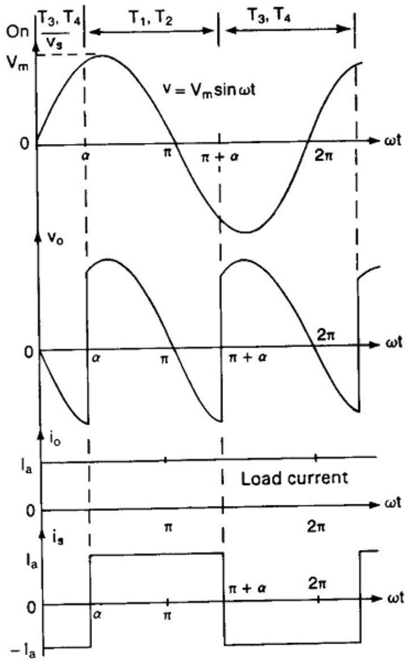


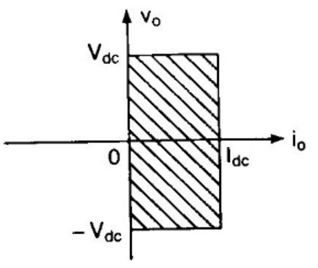
3-



Single Phase Full Converters:







$$V_{dc} = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin\omega t \, d(\omega t) = \frac{2V_m}{2\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi+\alpha} = \frac{2V_m}{\pi}\cos\alpha$$

$$V_{rms} = \left[\frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m^2 \sin^2\omega t \, d(\omega t)\right]^{1/2} = \left[\frac{V_m^2}{2\pi}\int_{\alpha}^{\pi+\alpha} (1-\cos 2\omega t)\, d(\omega t)\right]^{1/2}$$

$$= \frac{V_m}{\sqrt{2}} = V_s$$

The rms current of a thyristor,

$$I_R = \left[\frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} i_L^2 \; d(\omega t)\right]^{1/2}$$

The rms output current

$$I_{rms} = \left(I_R^2 + I_R^2\right)^{1/2} = \sqrt{2}\, I_R$$

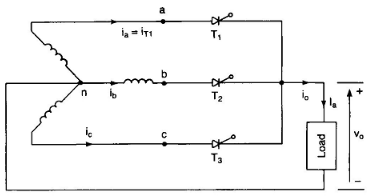
The average current of a thyristor

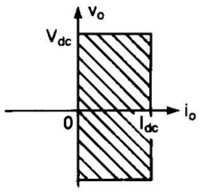
$$I_A = \frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} i_L \; d(\omega t)$$

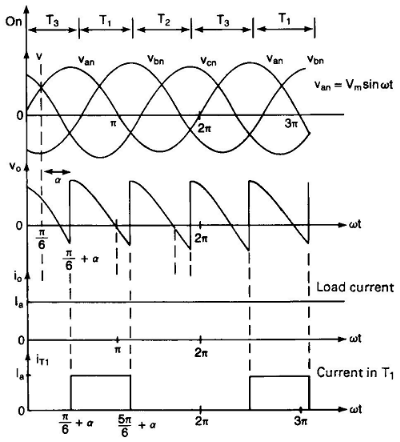
The average output current

$$I_{dc} = I_A + I_A = 2I_A$$

Three-phase Half-Wave Converters:







If the phase voltage is $v_{an} = V_m \sin \omega t$,
the average output voltage for a continuous load current is

$$V_{dc} = \frac{3}{2\pi} \int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin \omega t \; d(\omega t) = \frac{3\sqrt{3}\, V_m}{2\pi} \cos\alpha$$

V_m : *peak phase voltage*

The maximum average output voltage that occurs at delay angle, $\alpha = 0$ *is*

$$V_{dm} = \frac{3\sqrt{3}\, V_m}{2\pi}$$

The normalized average output voltage is

$$V_n = \frac{V_{dc}}{V_{dm}} = \cos\alpha$$

The rms output voltage is

$$V_{rms} = \left[\frac{3}{2\pi} \int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m^2 \sin^2 \omega t \; d(\omega t) \right]^{1/2}$$

$$= \sqrt{3}\, V_m \left(\frac{1}{6} + \frac{\sqrt{3}}{8\pi} \cos 2\alpha \right)^{1/2}$$

For the resistive load and $\alpha \geq \pi/6$:

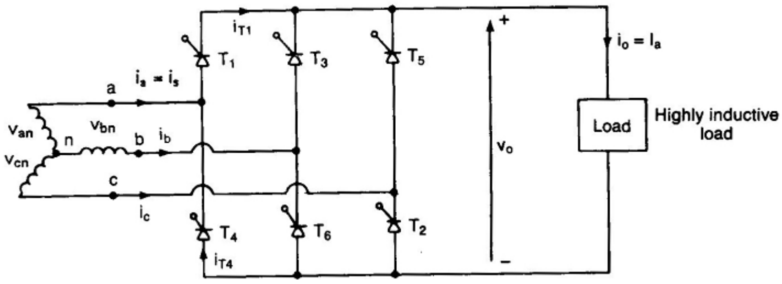
$$V_{dc} = \frac{3}{2\pi} \int_{\pi/6+\alpha}^{\pi} V_m \sin \omega t \; d(\omega t) = \frac{3V_m}{2\pi} \left[1 + \cos\left(\frac{\pi}{6} + \alpha \right) \right]$$

$$V_n = \frac{V_{dc}}{V_{dm}} = \frac{1}{\sqrt{3}}\left[1+\cos\left(\frac{\pi}{6}+\alpha\right)\right]$$

$$V_{rms} = \left[\frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m^2 \sin^2 \omega t \; d(\omega t)\right]^{1/2}$$

$$= \sqrt{3}\, V_m\left[\frac{5}{24} - \frac{\alpha}{4\pi} + \frac{1}{8\pi}\sin\left(\frac{\pi}{3}+2\alpha\right)\right]^{1/2}$$

Three Phase Full Converters:



Frequency out put ripple =6 fs

If, line − to − neutral voltages

$$v_{an} = V_m \sin \omega t$$

$$v_{bn} = V_m \sin\left(\omega t - \frac{2\pi}{3}\right)$$

$$v_{cn} = V_m \sin\left(\omega t + \frac{2\pi}{3}\right)$$

corresponding line − to − line voltages

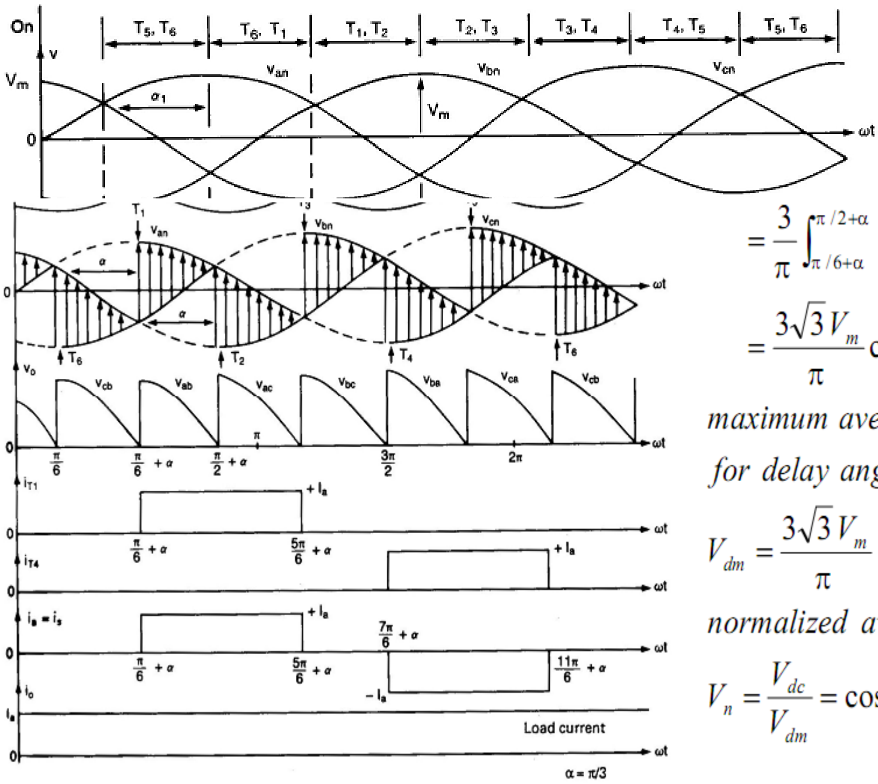
$$v_{ab} = v_{an} - v_{bn} = \sqrt{3}\, V_m \sin\left(\omega t + \frac{\pi}{6}\right)$$

$$v_{bc} = v_{bn} - v_{cn} = \sqrt{3}\, V_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$v_{ca} = v_{cn} - v_{an} = \sqrt{3}\, V_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

average output voltage:

$$V_{dc} = \frac{3}{\pi}\int_{\pi/6+\alpha}^{\pi/2+\alpha} v_{ab} \;\; d(\omega t)$$



$$= \frac{3}{\pi}\int_{\pi/6+\alpha}^{\pi/2+\alpha} \sqrt{3}V_m \sin\left(\omega t + \frac{\pi}{6}\right) d(\omega t)$$

$$= \frac{3\sqrt{3}V_m}{\pi}\cos\alpha$$

maximum average output voltage

for delay angle, $\alpha = 0$

$$V_{dm} = \frac{3\sqrt{3}V_m}{\pi}$$

normalized average output voltage

$$V_n = \frac{V_{dc}}{V_{dm}} = \cos\alpha$$

$$V_{rms} = \left[\frac{3}{\pi}\int_{\pi/6+\alpha}^{\pi/2+\alpha} 3V_m^2 \sin^2\left(\omega t + \frac{\pi}{6}\right) d(\omega t)\right]^{1/2}$$

$$= \sqrt{3}V_m\left(\frac{1}{2} + \frac{3\sqrt{3}}{\pi}\cos 2\alpha\right)^{1/2}$$

Thyristors Commutation Techniques:

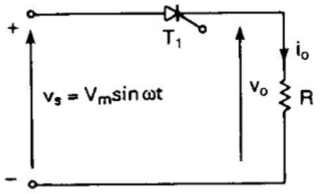
(a) Natural Commutation
(b) Forced Commutation

If the source (or input) voltage is ac, the thyristor current goes through a natural zero, and a reverse voltage appears across the thyristor. The device is then automatically turned off due to the natural behavior of the source voltage.

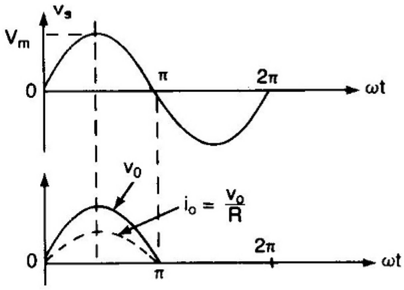
(Natural commutation or Line commutation)

: ac voltage controllers, phase-controlled rectifiers,

cycloconverters



(a) circuit



(b) waveforms

Forced Commutations:

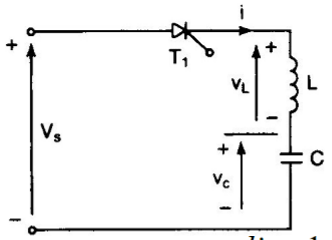
In some thyristor circuits, the input voltage is dc *and the forward current of the thyristor is forced to zero by an additional circuitry called commutation circuit to turn off the thyristor.*

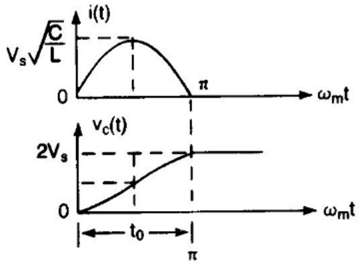
(Forced commutation)

: dc-dc converters (choppers), dc-ac converters (inverters)

1. **Self-commutation**
2. **Impulse commutation**
3. **Resonant pulse commutation**
4. **Complementary commutation**
5. **External pulse commutation**
6. **Load-side commutation**
7. **Line-side commutation**

1. Self-commutation:



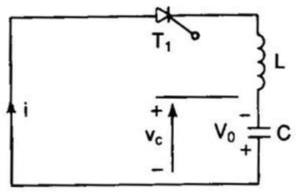


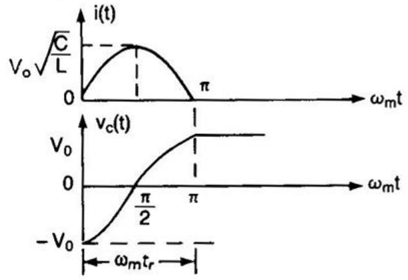
$$V_s = v_L + v_c = L\frac{di}{dt} + \frac{1}{C}\int i\ dt + v_c(t=0)$$

$$initial\ conditions,\quad v_c(t=0) = 0,\quad i(t=0) = 0$$

$$charaging\ current,\ i(t) = V_s\sqrt{\frac{C}{L}}\sin\omega_m t,\qquad \because \omega_m = \frac{1}{\sqrt{LC}}$$

$$capacitor\ voltage,\ v_c(t) = V_s(1-\cos\omega_m t)$$





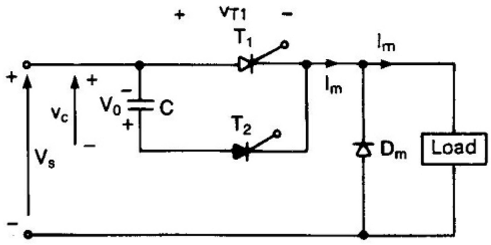
$$L\frac{di}{dt}+\frac{1}{C}\int i\ dt+v_c(t=0)=0$$

$$initial\ conditions,\ \ v_c(t=0)=-V_0,\ \ i(t=0)=0$$

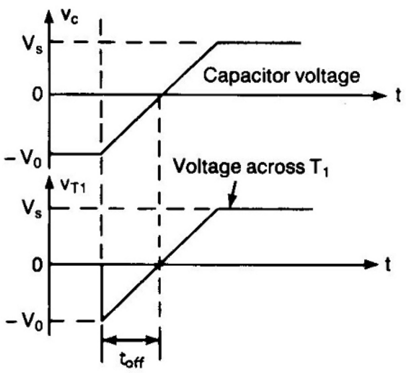
$$capacitor\ current,\ \ i(t)=V_0\sqrt{\frac{C}{L}}\sin\omega_m t,\qquad \because \omega_m=\frac{1}{\sqrt{LC}}$$

$$capacitor\ voltage,\ \ v_c(t)=-V_0\cos\omega_m t$$

2. *Impulse-commutation*



Thyristor and capacitor voltages



$$turn-off\ \ time: t_q$$

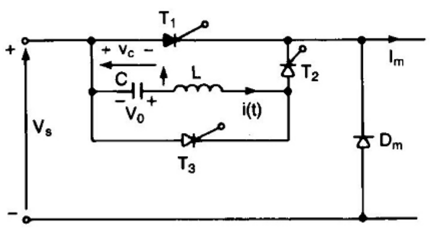
$$circuit\ turn-off\ \ time: t_{off}$$

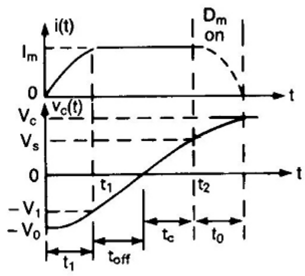
$$V_0=\frac{1}{C}\int_0^{t_{off}} I_m\, dt$$

$$=\frac{I_m t_{off}}{C}$$

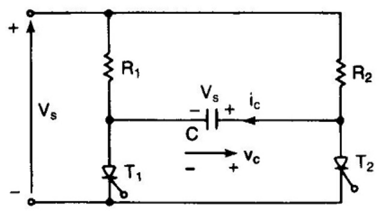
$$t_{off}=\frac{V_0 C}{I_m}$$

3. Resonant pulse commutation

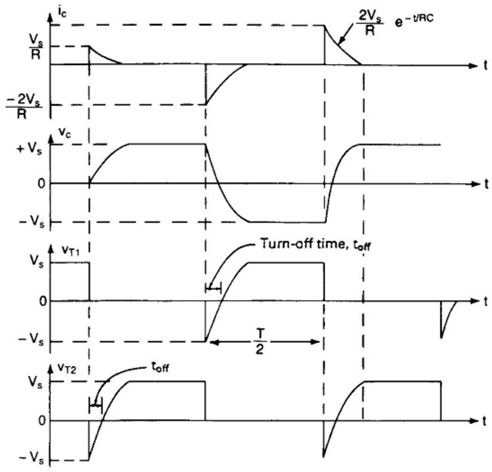




4. Complementary commutation

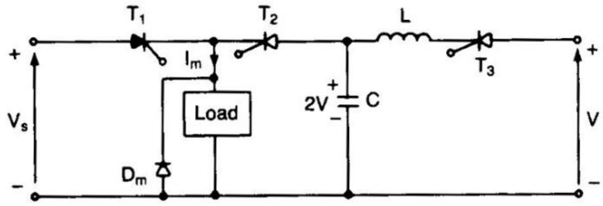


Circuit



Waveforms for R_1=R_2=R

5. External pulse commutation



V_s : voltage of the main supply

V : voltage of the auxiliary source

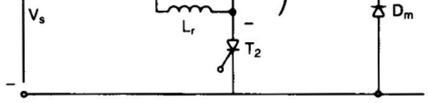
6. Load-side commutation

In load-side commutation, the load forms a series circuit with the capacitor ; and the discharging and recharging of the capacitor are done through the load.

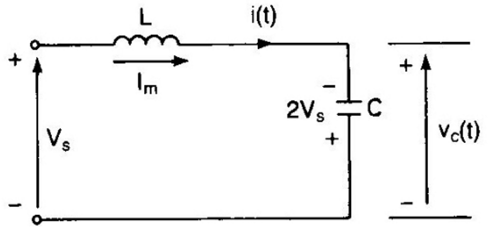
The performance of load-side commutation circuits depend on the load and in addition the commutation circuits cannot be tested without connecting the load.

7. Line-side commutation

In this type of commutation, the discharging and recharging of the capacitor are not accomplished through the load and commutation circuit can be tested without connecting the load.

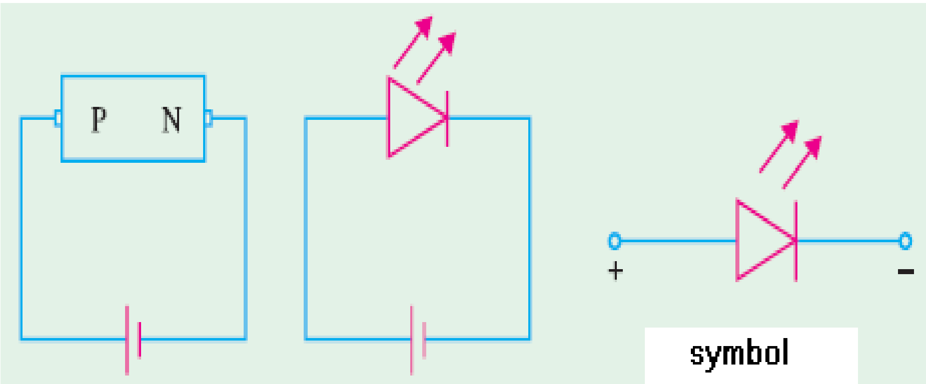


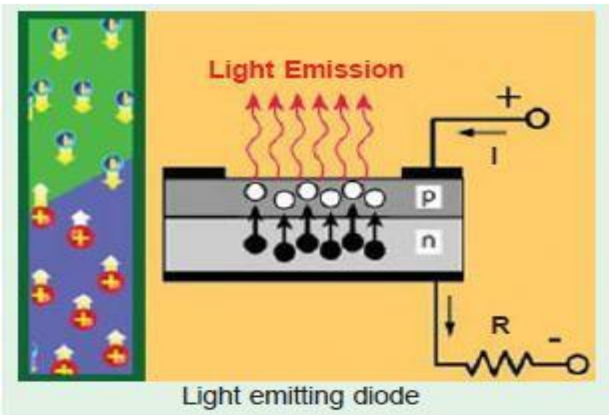
Equivalent circuit during commutation period

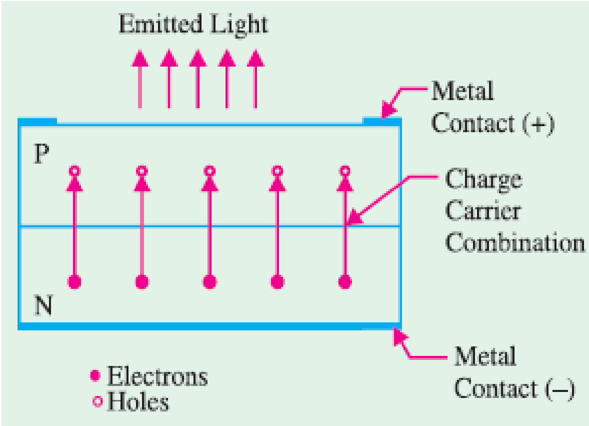


Opto-electronic devices

1- Lighting Emitting Diode (LED)






Emitted Light
Metal
Contact (+)
P
Charge
Carrier
Combination
N
Metal
Contact (–)
Electrons
Holes

(LED) characteristic :-

The forward voltage across an LED is considerably greater than for a silicon *PN* junction diode. Typically the maximum forward voltage for LED is between 1.2 V and 3.2 V depending on the device. Reverse breakdown voltage for an LED is of the order of 3 V to 10 V. Fig. (1) (*a*) shows a simple circuit to illustrate the working of an LED. The LED emits light in response to a sufficient forward current. The amount of power output translated into light is directly proportional to the forward current as shown in **fig (1) b** It is evident from this figure that greater the forward current, the greater the light output.

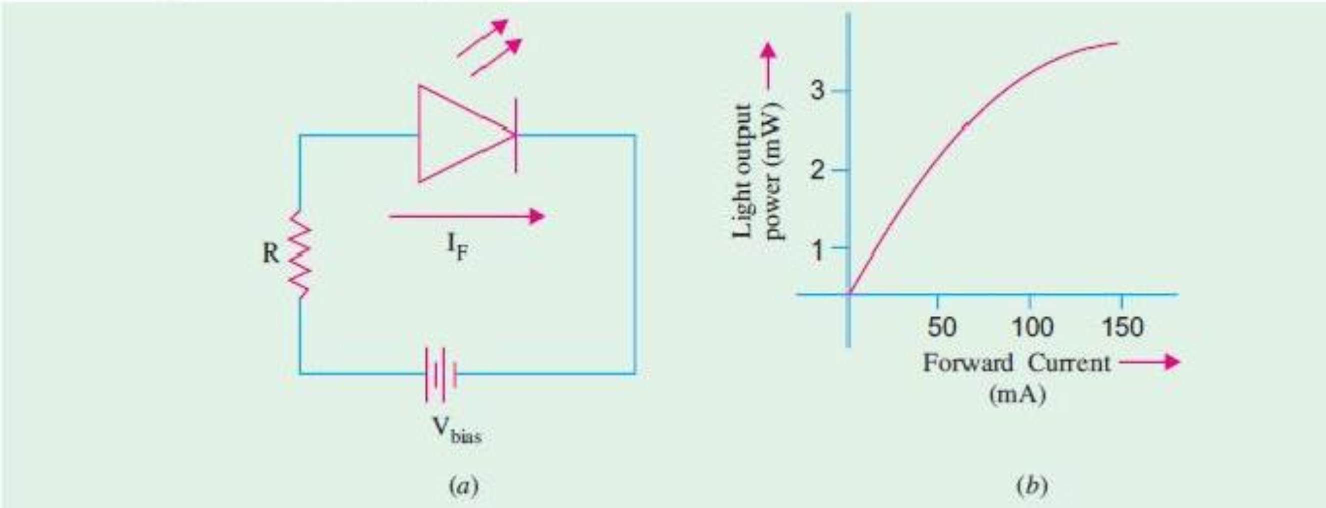
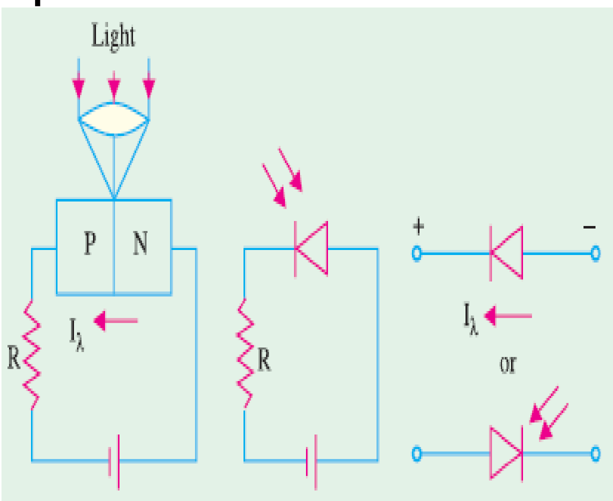


Fig (1)

1-photo diode :-

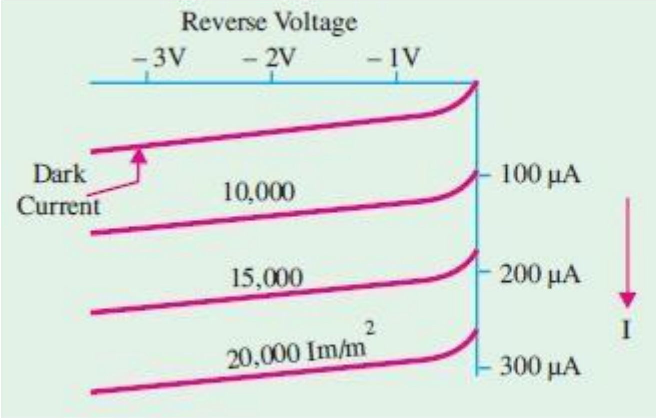


Fig(1) symbol and circuit

Photodiode

fig (2) photodiode

photo diode characteristic :-



2- photoconductive cells:-

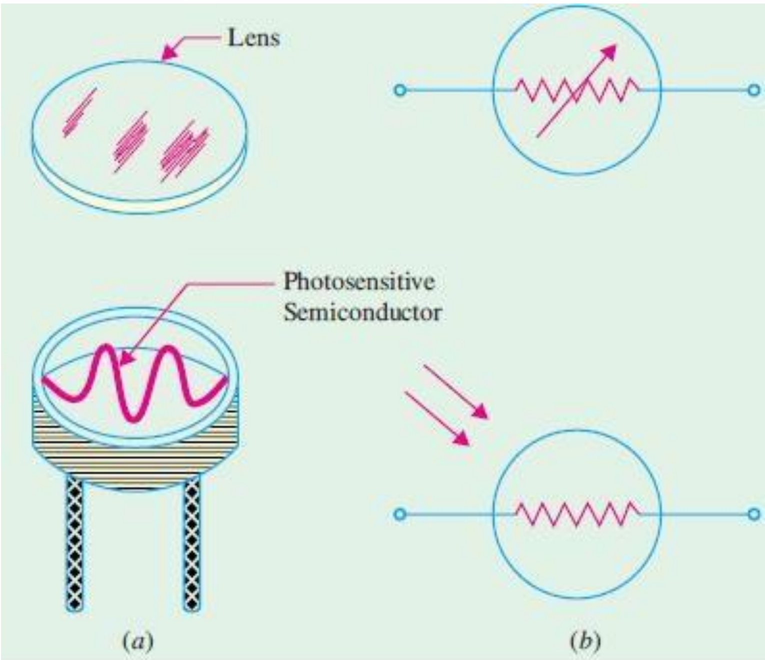
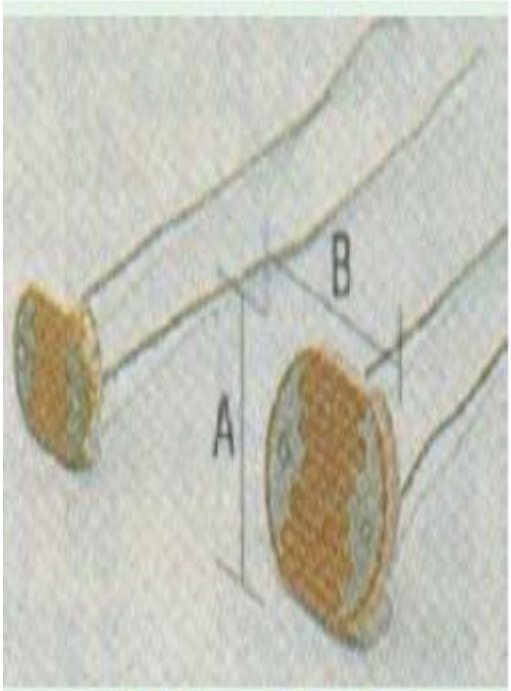
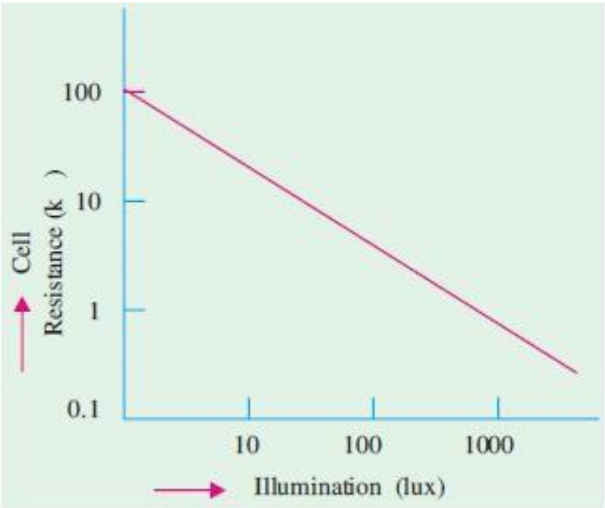


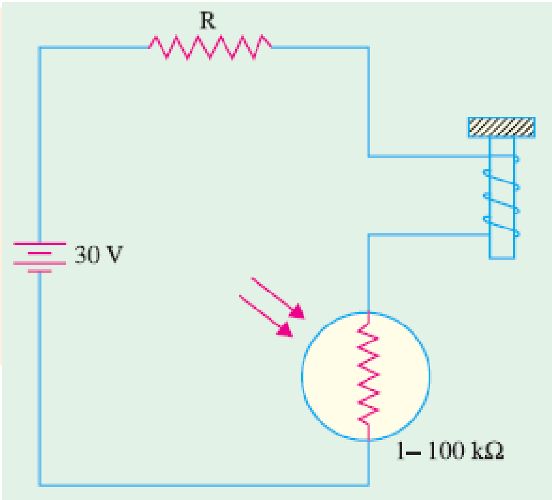
fig.1



CdS photo sensitive detectors

Photoconductive cell characteristic :-





Fig(1) photoconductive cell characteristic **Fig(2) photoconductive cell circuit**

3-photo transistor :-

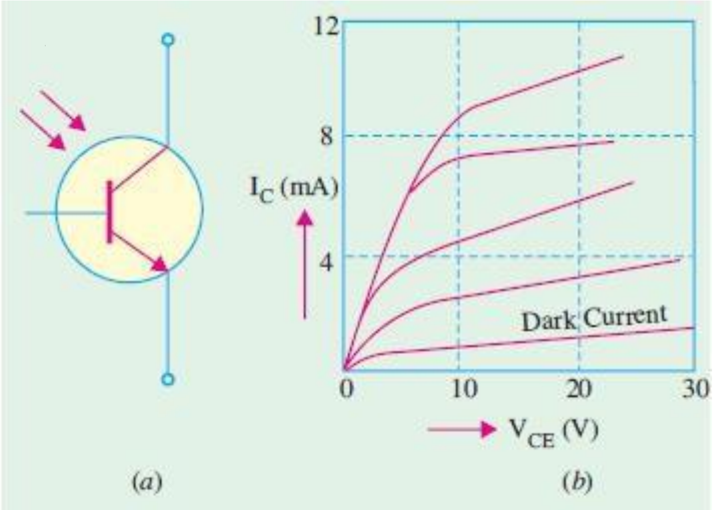
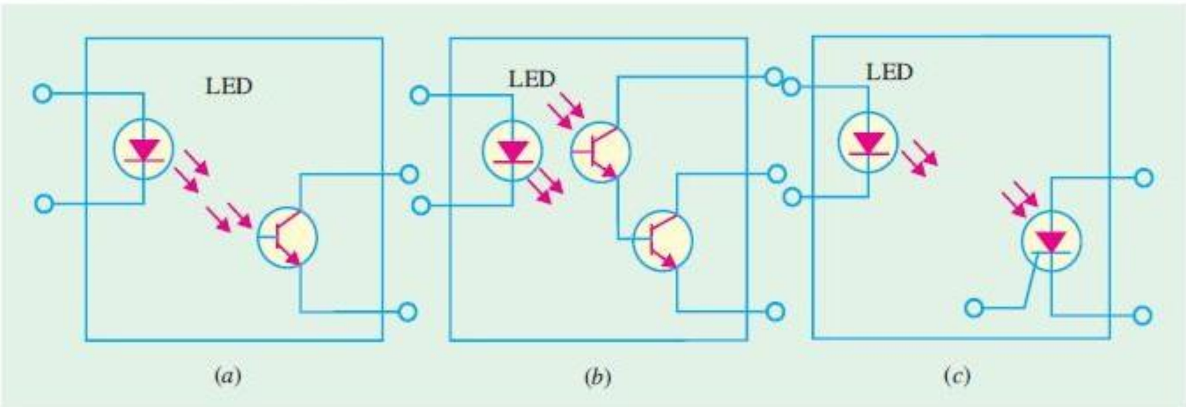


Fig (1) a) symbol b) characteristic fig(2) phototransistor

5 — Optical Isolators

Optical isolators are designed to electrically isolate one circuit from another while allowing one circuit to control the other. The usual purpose of isolation is to provide protection from high-voltage transients, surge voltages and low-level electrical noise that could possibly result in an erroneous output or damage to the device. Such isolators allow interfacing of circuits with different voltage levels and different grounds etc.



Chapter Two

DC Chopper:(DC to DC Converter):

Principle of step-down operation:

Step-down chopper with resistive load

Chopper switch: power BJT; power MOSFET, GTO forced-commutated thyristor.

Step-down chopper with RL load:

At the end of model 2

Principle of step-up operation:

Chapter Three

AC to AC

Converter

Star Connected Resistive Load:

Delta-Connected Resistive Load:

Chapter Four

DC to AC Converters

(Inverter)

Voltage Source Inverters

Introduction:

Fig 1 General block diagram

Principle of operation:

$V_o = V_s/2$

$$V_1 = \frac{2V_s}{\sqrt{2}\,\pi} = 0.45\ V_s$$

Fig 2 The circuit and waveforms with inductive load

Performance Parameter :

Harmonic Factor, HF*: is defined as* $HF_n = \dfrac{V_n}{V_1}$

Total harmonic distortion, THD*:*

$$THD = \frac{1}{V_1}\left(\sum_{n=2,3\ldots}^{\infty} V^2{}_n \right)$$

Distortion factor, DF:

$$DF_n = \frac{V_n}{V_1 n^2}$$

Single –Phase Bridge Inverter*:*

Fig3 the circuit

Fig 4 Waveforms of output voltage and load current for inductive loads

$$V_0 = \sqrt{\frac{2}{To} \int_0^{To/2} Vs^2\, dt} = Vs$$

$$V_1 = \frac{4Vs}{\sqrt{2}\,\pi} = 0.9\ Vs$$

Solution:

a) $V_1 = \frac{4Vs}{\sqrt{2}\,\pi} = 0.9\ Vs = 0.9 \times 48 = 43.2\ V$

b) $Vo = \sqrt{\frac{2}{To}\int_0^{To/2} Vs^2\ dt} = Vs = 48V$

The output power $Po = V_s^2/R = 960W$.

c) $Ip = 48/2.4 = 20A$. I_D *of each transistor is* $0.5 \times 20 = 10A$.

d) $V_{BR} = 48V$.

e) $V_1 = \frac{4Vs}{\sqrt{2}\,\pi} = 0.9\ Vs = 0.9 \times\ 48 = 43.2\ V$

$$Vh = \sqrt{\sum_{n=3,5,7....}^{\infty} V^2\ n} = \sqrt{Vo^2 - V_1^2} = 0.435Vs$$

$$THD = \frac{1}{V_1}\left(\sum_{n=2,3,...}^{\infty} V^2\, n\right) = \frac{0.4359Vs}{0.9\,Vs} = 48.34\%$$

f) $DF = \frac{1}{V1}\sqrt{\sum_{n=2,3,...}^{\infty}\left(\frac{Vn}{n^2}\right)^2} = \frac{0.0342\,Vs}{0.9Vs} = 3.804\ \%$

g) *The lowest-order harmonic is the* 3rd, $V_3 = V_1/3$

$$HF_3 = \frac{V3}{V_1} = 1/3 = 33.33\%$$

$V_3/3^2$

$$DF_3 = \frac{\quad}{V_1} = 1/27 = 3.704\%$$

EX:2/

An inductive load of resistive of 10Ω and inductive of 10mH is to be supplied with a ***Quasi Square waveform*** *voltage, using single-phase bridge inverter. If the on periods is to be 1/2 of the total period ,load frequency = 200Hz and the dc supply available is 200V, trace with calculated dimensions for the first cycle.*

A) Load voltage waveform.

B) Load current waveform.

Solution :

$$i_L = \frac{V}{R}\left(1 - e^{-\frac{Rt}{L}}\right) + I\min e^{-\frac{Rt}{L}}$$

$$To = \frac{1}{f} = \frac{1}{200} = 5 \text{ msec.}$$

2a = 0.5 To a=1.25 msec.

1) +Ve = 200V on half period i_L = 0 at t=0

$$i_L = \frac{200}{10}\left(1 - e^{-1000t}\right) + 0 = 14.27A \qquad at\ \ t = 1.25\ msec.$$

2) Ve off half period V_L = 0V Imin = 14.27 A

بعد التعويض في المعادلة قيمة التيار تساوي

i_L = 4A

3) –Ve on period V_L = -200V Imin = 4A

بعد التعويض في المعادلة قيمة التيار تساوي

i_L = - 13.12A

4) Ve off half period V_L = 0V Imin = -13.12A

بعد التعويض في المعادلة قيمة التيار تساوي

i_L = - 3.75A

EX:3/*A single-phase bridge inverter supplies from 200Vdc source a load of R= 8Ω and inductive of 20mH if the inverter is operating at 50Hz. Determine the load voltage and current waveforms for the first two cycles with* ***square wave*** *output.*

Solution:

$$i_L = \frac{V}{R}\left(1 - e^{-\frac{Rt}{L}}\right) + I\min e^{-\frac{Rt}{L}}$$

To = 1/(f) = 1/50= 0.02 sec = 20 msec.

a = 0.5 To = b =0.01 sec = 10 msec.

At t=0 , i = Io = 0 A

1) First cycle : +Ve = 200V on half period i_L = 0 initial current. at t= To/2 = 0.01 sec .

$$i = \frac{200}{8} + \left(0 - \frac{200}{8}\right) e^{-\frac{8\times 0.01}{0.02}} = 24.54A$$

2)- Ve half period VL = -200V, Imin = $24.54A$, t = 0.01 sec. = 10 msec.

بعد التعويض في المعادلة قيمة التيار تساوي

i = -24. 1A

3) For second cycle :+Ve half period third half cycle

V_L = 200V Io = -24. 1A at t= 0.01 sec.=10msec.

بعد التعويض في المعادلة قيمة التيار تساوي

i =24.1A

4) -Ve half cycle period (4^{th} half cycle)

V_L = -200V, Io =24.1A at t= 0.01 sec.=10msec.

بعد التعويض في المعادلة قيمة التيار تساوي

i = - 24.1 A

الان بعد حل السؤال سأضيف عليه وهذا الحل واجب بيتي على المشاهد

Determine the time when load current is equal to zero?

Solution :

T= 1.7 msec.

EX:4/A *single-phase bridge inverter supplies from 200Vdc source a load of R= 8Ω and inductive of 20mH if the inverter is operating at 50Hz. Determine the load voltage and current waveforms for the first cycle with* ***Quasi square*** *wave output with an on period of 0.6 total period.*

Solution:

2a+2b= T, 2a= 0.6T , T= 1/50 = 0.02sec. , a= 6 msec. , b= 4 msec.

$$i_L = \frac{V}{R}\left(1 - e^{-\frac{Rt}{L}}\right) + I\min e^{-\frac{Rt}{L}}$$

الحل موجود حاول التحقق من القيم

الان ممكن ان تضيف الى السؤال جد قيمة t عندما تكون قيمة تيار الحمل = صفر

Solution : t = 0.42 ms

Voltage control of single phase inverters:

Pulse width modulation (PWM) control:

1)Single –pulse- width modulation:

Fig 7single pulse width modulator *Fig8 Harmonic profile of SPWM*

$$M= \frac{Ar}{Ac} \qquad Vo= \sqrt{\frac{2}{2\pi}\int_{(\pi-\delta)/2}^{(\pi+\delta)/2}(Vs)^2\, d(wt)} = Vs\sqrt{\frac{\delta}{\pi}}$$

The RMS output voltage can be found from:

$$V_0(t)= \sum_{n=1,3,5,\ldots}^{\infty}\frac{4Vs}{n\pi}\sin\frac{n\delta}{2}\ \sin nwt$$

2)Multiple - pulse- width modulation:

$$P= \frac{fc}{2fo}$$

Fig 9 Multiple – PWM *Fig 10 harmonic profile of M-PWM*

The RMS output voltage can be found from:

$$Vo = \sqrt{\frac{2P}{2\pi}\int_{\frac{\left(\frac{\pi}{p}\right)-\delta}{2}}^{\frac{\left(\frac{\pi}{p}\right)+\delta}{2}} (Vs)^2\ d(wt)} = Vs\sqrt{\frac{p\delta}{\pi}}$$

3)Sinusoidal pulse- width modulation:

$$Vo = Vs\sqrt{\sum_{m=1}^{p}\frac{\delta m}{\pi}}$$

Fig 11 (a,b) SPWM *Fig 12 harmonic profile of SPWM*

4)Modified sinusoidal pulse- width modulation:

$$\frac{fc}{fo} = 6q + 3$$

Fig 13 Modified sinusoidal pulse- width modulation

5-Phase-displacement control:

$$Vo = Vs\sqrt{\frac{\beta}{\pi}} \quad \text{if}$$

$$vao = \sum_{n=1,3,5,\ldots}^{\infty} \frac{2Vs}{n\pi} \sin nwt \qquad \text{then}$$

$$vbo = \sum_{n=1,3,5,\ldots}^{\infty} \frac{2Vs}{n\pi} \sin n(wt - \beta)$$

$$vab = vao - vbo = \sum_{n=1,3,5,\ldots}^{\infty} \frac{2Vs}{n\pi}\{\sin nwt - \sin n\,(wt - \beta)\}$$

Fig 14(a,b,c,d,e) Phase-displacement control

$$vab = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4Vs}{n\pi} \left\{ \sin \frac{n\beta}{2} \cos n\left(wt - \frac{\beta}{2} \right) \right\}$$

The rms value of the fundamental output voltage is:

$$V_1 = \frac{4Vs}{\sqrt{2}\,\pi} \sin \frac{\beta}{2}$$

Voltage control of three phase inverter:

Fig 15Sinusoidal pulse- width modulation for three phase inverter

Harmonic reduction:

Sin nβ / 2 = 0 or β = 360˚ / n

$$vab= \sum_{n=1,3,5,...}^{\infty} \frac{4Vs}{n\pi} \{ \sin\frac{n\beta}{2} \cos n (wt - \frac{\beta}{2}) \}$$

and the 3[rd] harmonic will be eliminate if β = 360˚ / 3 = 120˚.

Fig 16 out put voltage with two notches per half-cycle

$$vo = \sum_{n=1,3,5...}^{\infty} An \sin nwt$$

Where

The 3[rd] and 5[th] harmonics would be eliminated if A3=A5=0

Fig 17 output voltages for MSPWM

$$v_o= \sum_{n=1,3,5...}^{\infty} \frac{4Vs}{n\pi} \sin nwt$$ *the output of 1[st] inverter can be expressed as*

$$vo_1= A_1 \sin wt +A_3 \sin 3wt +A_5 \sin5wt +.......$$

Fig 18 Elimination of harmonics by transformer connection